Systematic Agricultural Geography

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Agricultural Geography

Majid Husain

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To
my teacher and supervisor
Prof. Mohammad Shafi

Preface

The *Systematic Agricultural Geography* is a higher level textbook, written to meet the requirements of the post-graduate and research students who wish to specialize in the field of Agricultural Geography. Agriculture still being the dominant economic activity in the developing world has great potential for those who are interested in the spatial distribution of agricultural systems and agricultural processes. It is, however, a product of the post-Second World War period as prior to that agriculture used to be investigated and interpreted through either Regional Geography or Economic Geography. At present, the major thrust of Agricultural Geography is on the description, interpretation and explanation of spatial variations of land use, cropping patterns, crop concentration, crop combination, agricultural productivity, agricultural regionalization and regional inequalities in agricultural efficiency with the set objective to formulate strategies for the planning and development of agriculture. For providing a strong theoretical base, models and theories of agricultural land use are also important components of Agricultural Geography. Agricultural models help in squeezing out the maximum amount of information from the available legion of data and thus have great utility for making more reliable predictions about agricultural activities and processes. All these aspects have been carefully examined in the present book.

The book is divided into eleven chapters and documented with nearly one hundred maps and diagrams. The definitions, nature,

growth and development and approaches to Agricultural Geography have been given in Chapter 1. Agriculture or domestication of plants and animals is a recent phenomenon in the cultural history of mankind. The main areas of domestication of plants and animals (gene-centres), the diffusion of crops and agricultural technology over the last about ten thousand years have been concisely presented in Chapter 2. Variations in agricultural processes over the earth surface are the manifestations of diversity in physical and cultural environment. In fact, the agricultural activity of a region is largely controlled by terrain, topography, slopes, texture of soils, temperature, rainfall, frost and other associated weather phenomena. The impact of physical factors on agricultural processes has been discussed with suitable examples in Chapter 3. The rapid growth of population in the developing countries and the increasing consumerism in the developed countries have induced intensification of agriculture and pushed its frontiers in the fragile ecosystems. The role of socioeconomic and political factors in the decision making process of farmers in the various agroclimatic regions has been examined in Chapter 4.

The concept of 'agricultural systems' is a dynamic one as they vary in space and time. The spatial dimension of the major agricultural systems and their salient attributes have been succinctly presented in Chapter 5 There is enormous growth of agricultural data in the recent decades. The vital sources of agricultural statistics, the techniques of fieldwork, collection of data, their classification and techniques have been examined in Chapter 6, while Chapter 7 deals with the main concepts, techniques and methods of agricultural regionalization. The philosophy, attributes and limitations of agricultural models and theories have been discussed in detail in Chapter 8.

The limited arable land puts a limit on the absolute capacity of the earth to support human beings. In fact, there are gross differences among groups of people with regard to their food supplies. The rich are abundantly, even wastefully fed, the poorest live perpetually on the brink of famine. Chapter 9 describes the nutritional status of human population and the outlook of meeting future needs for food. The deficiency diseases prevalent rampantly in the developing countries have also been discussed in this chapter. The main characteristics of Indian agriculture, the barriers in its development and the

planning strategies during the Five Year Plans have been presented in Chapter 10, while Chapter 11 gives a cogent account of the diffusion of High Yielding Varieties in Indian agriculture. The performance, problems and prospects and the socioecological consequences of the Green Revolution in India have been critically examined in this chapter.

In view of the pressing demand from students, specially those who are probing in the spatial mosaic of agriculture and those preparing for Civil Service and various other competititive examinations, it was Mr. K. Rawat who inspired me to go for the present venture for which I must express my sincere thanks. Mr. K.K. Parnami went through the manuscript carefully and did the arduous task of editing courteously and meticulously for which I am indebted. Mr. Ganga Sharan deserves my special thanks for the preparation of maps and diagrams. His skill and dexterity in conventional cartography made the maps and diagrams more attractive and meaningful. I also wish to thank the members of my family for their cooperation and for bearance. The wonderful company and refreshing innocent smiles of Master Abshoo-Amjad Abdul-Rehaman always stimulated me to concentrate increasingly in my academic pursuits for which I feel indebted. My wife, who like most of the Indian women, suffered a lot, deserves special thanks. Thanks are also due to Javed Alam, Shagufta Bano Husain, Mansoor Majid, Abdul Rahman, Mehdi Asad, Shahida Naz and Madeha. Finally, I am thankful to all my teachers, colleagues, relatives and friends for their guidance and help. However, all the inaccuracies in the text are my responsibility. Constructive criticism and suggestions are invited to improve the subsequent editions of the book.

Majid Husain

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1 Nature of Agricultural Geography

To define present-day 'agricultural geography' is a matter of considerable debate among professional geographers. Etymologically, agricultural geography deals with the art and science of domestication of plants and animals. Its definitions are numerous which have changed over the period of time. Some of the important definitions of agricultural geography have been given here under.

1. According to Johnston (1985) agricultural geography has been defined as the study of spatial variations in agricultural activity, involving both the description of such variations and attempts to explain them.

This definition has been widely accepted by geographers as it describes not only the spatial (regional) variations of agricultural phenomena but also explains the geoecological and socioeconomic bases of such variations. This definition may be made clear with the help of an illustration. For example, a large number of commercial cash crops are grown in tropical and subtropical regions but their cultivation and concentration depend on the geoclimatic requirements of the crop. Some crops such as rubber, oil-palm, cocoa, banana, coffee and spices are produced closely in the tropics, whereas the cultivation of other crops such as cotton, tobacco, sugarcane, groundnut (peanut) and tea extends to areas that lie in subtropic and temperate regions. The question is why the cultivation of these case crops is concentrated into different climatic regions. To answer this question and to

explain the spatial variations of such cropping patterns is the task of agricultural geographers. Similarly, the cultivation of jute in the subcontinent of India is largely confined to the plain areas of West Bengal, and to a few districts of western Assam, eastern Bihar and Orissa. The demarcation of jute region, its description and explanation are to be provided by agricultural geographers

2 According to Hillman (1911) agricultural geography deals with a comparative study of agriculture of countries and continents. Given in 1911, it is an obsolete definition. The basic focus of this definition is to compare the agricultural activities of different countries and continents at a macro level. In reality, the decisions about the cropping patterns and associated activities are taken at the field or micro level Moreover, this definition does not explain the causes of such spatial variations in agricultural phenomena.

3. Bernhard (1915) defines agricultural geography as the study of *regional variations in agriculture and the factors responsible for* them. It is a relatively more rational definition of agricultural geography as it takes into account the regional distribution of agricultural activities. It also attempts to identify the physical and cultural factors which control the spatial distribution of agricultural pursuits.

4. In the opinion of Reed (1964) agricultural geography deals with the description and explanation of regional differentiation of agricultural characteristics. There are numerous agricultural typologies and systems in the world. The salient characteristics of these agricultural systems differ from each other. According to Reed, agricultural geographers should examine, analyze and interpret the main causes of spatial variations in these attributes. For example, the rice region differs from the *bajra* (bulrush-millet) region in India. There may be geoclimatic, pedological and socioeconomic reasons for the cultivation of these crops into different parts of the country. An agricultural geographer can identify the underlying causes of such variations. He also attempts some explanation of how they came into being.

5. Andreae (1981) opines that agricultural geography is the science of agriculturally transformed earth's surface with all its associated physical, social and economic interrelationships as reflected spatially. The main focus of this definition is on the point that over the period of last over 12000 years, man by his deeds has trans-

formed the natural vegetation. He has modified the natural ecosystems into agricultural ecosystems. The agricultural geographers with the help of some indicators can divide the earth surface into different, agricultural types or systems Subsequently, these systems need to be described, analyzed and explained.

6. According to Coppock (1969), in agricultural geography agricultural facts are arranged in an orderly manner. He emphasized that the main task of an agricultural geographer is to collect data for the testing of hypothesis and to provide adequate explanation for the spatial distribution of agricultural activities. Coppock, in his definition, has given adequate emphasis on the purpose of agricultural geography and the methodology to be adopted for the formulation of agricultural models, paradigms, theories and generalizations.

7. Agricultural geography has also been defined as the science which deals with the regional or spatial variations in the distribution of agricultural entities and to explain the causes of such variations.

8. Symon (1970) defines agricultural geography as man's husbandry of the land

Apart from the above definitions, agricultural geography has also been defined as the science of areal arrangement of agricultural phenomena. In the opinion of others, agricultural geography refers to the field of study focused on the location of agricultural activities at the local, regional, national and world scales. Some scholars opine that agricultural geography is the science of relationship between the physical environment and the forms of agrarian life.

These definitions clearly show that the geographers differ much in their opinions about the definition of agricultural geography. In fact, like all the other disciplines of knowledge, the definition of this subbranch of geography is also changing in space and time. Whatsoever the differences in the definitions may be, the subject matter of agricultural geography is the plants and animal husbandry. It would be of great interest to know the nature, methodology and approaches to agricultural geography A brief description of these aspects of the discipline has been given in the following paras.

As discussed at the outset the main focus of agricultural geogra-

phy is on the spatial variation of agricultural phenomena In modern agricultural geography the major thrust of geographers is to investigate the spatial variability of agricultural activity Land use is the most obvious spatial variable and much effort has gone into describing and classifying land uses (crop combinations crop concentration, crop diversification, agricultural efficiency, land use survey and land carrying capacity regions) In the explanation of land uses, other farming variables, such as land tenure, field size size of holdings and labour supply must be taken into consideration along with the physical variables (viz ,terrain, temperature, moisture, soils, etc) and economic variables (viz , irrigation, fertilizers, technology, etc) and the value of outputs For a comprehensive study of agricultural geography a unified approach, based on physical, social, cultural, economic and infrastructural variables has to be adopted

Objectives of Agricultural Geography

The main objectives of agricultural geography are

(i) To examine the spatial distribution of crops, livestock and other agricultural activities The cropping patterns and crop and livestock combinations vary in space and time For example, the crop associations of Punjab and Haryana are different from those of Rajasthan, Bihar and West Bengal The causes of such variations and their systematic explanation is one of the primary objectives of agricultural geographers

(ii) To ascertain the spatial concentration of agricultural phenomena There are certain crops which have very high concentration in one area and low or insignificant concentration in other areas The reasons for such spatial densities are examined by agricultural geographers

(iii) Crop associations and crop livestock combinations change in space and time What was the crop combination in Punjab in the pre-Green Revolution period has changed in the post-Green Revolution period In fact, the wheat and rice combination in Punjab and Haryana is a recent development in the crop land use history of these states This association is not going to last as many of the farmers and scientists are rightly

challenging its sustainability There is a strong possibility of the farmers to adopt a new combination in the coming decades The farmers always try to optimize their agricultural returns and adopt new innovations The temporal change in cropping patterns deserves investigation and explanation

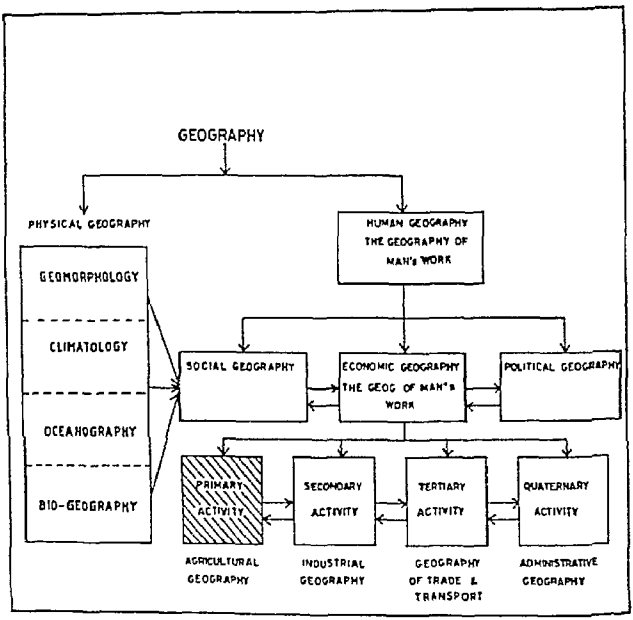
(iv) The performance of various crops in a country or region is not uniform There are inter-regional, intra-regional, intra-village and intra-farm variations in the production and productivity of different crops In other words, some areas perform better than others agriculturally The reasons why certain areas are lagging behind in agricultural productivity is also a fascinating ground of agricultural geographers

(v) Apart from the given objectives, the agricultural geographers have to diagnose at the micro level (household and field level) the causes of existing agricultural backwardness, and then to suggest suitable strategies to enhance productivity This may go a long way in alleviating the marginal and small farmers above the poverty line in a given region

(vi) In the developed countries and in some pockets of developing countries, agriculture has achieved the status of 'agribusiness' In agribusiness agriculture has been considered as an industry in which the 'law of increasing return' applies The geographers should make attempt to identify the impediments which are coming in the way of making this occupation as an agribusiness

Agricultural geography as a subdiscipline of Human and Economic geography has been shown in Figure 1 1 The geography of human activities is called as 'economic geography' which examines the primary, secondary, tertiary and quaternary activities of man Man in his primeval stage was a hunter and gatherer and during the neolithic period he learned the art of cultivation of crops Thus, agriculture had been the dominant economic activity in the past and it is still the mainstay of over two-third of the world population The study of agricultural geography is thus of great social relevance among all the branches of human geography

Figure 1.1
Place of Agricultural Geography



Agricultural Geography : A Historical Perspective

The growth and development of agricultural geography is as old as the other accounts of geography. The Greek, Roman, Arab, Chinese and Indian geographers gave references of the agricultural activities, cropping patterns and variations in the dominant crops in the different parts of the then known world. The explorers of the 'Great Age of Discovery' and the founders of modern geography like Verenius, von Humboldt and Ritter also differentiated in the agricultural practices of the different regions they travelled. One may find isolated accounts of agricultural products in some writings of the medieval period. The first book on agricultural geography was written by Arthor Young. His monumental work *Environment and Cropping Patterns in England* was published in 1770. In his work Young attempted to establish a relationship between environment and agricultural phenomena. In his opinion, temperature, rainfall and soils are the major

determinants of cropping patterns of a region. After his return from South America and West Indies, Humboldt described the agricultural practices in the countries he visited and wrote in Kosmos *Land Use in Cuba and South America* in 1807. He adopted an inductive approach and established that the spread of cultivation in the forest areas of Cuba is the main cause of decrease in rainfall. Schwenz, another German geographer and a contemporary of Humboldt, was influenced by Arthor Young. He gave the first account of spatial distribution of crops in Germany in his book *Environment and Cropping Patterns in Germany*. Schwenz was essentially an environmental determinist who generalized that agricultural activities and cropping patterns are largely controlled by the prevailing temperature and amount of rainfall received in a region.

von Thunen was the first scholar who prepared a spatial model of agricultural land use and crop intensity. He propounded the agricultural land use model in 1826. The basic aim of von Thunen's work was to explain the prices of farm products and the way in which such prices control agricultural production on any plot of land. He produced a statement of the land use pattern to be expected in his contemporary agricultural environment.

For about one hundred years after von Thunen there was not much progress in agricultural geography except the contribution of Engelbrecht (1883) who prepared crop regions of North America. The geographers of nineteenth century concentrated more on the dichotomy of physical versus human geography. It was 1911 when Krzmowski attempted the scientific basis of agricultural geography and produced his scholarly work *Scientific Position of Agricultural Geography*. The first attempt of agricultural regionalization of Europe was made by Jonasson in 1926 in his work *Agricultural Regions of Europe*. Baker, one of the leading American geographers, published *Agricultural Regions of North America* in 1926. On the basis of areal strength Baker divided America into wheat, maize, cotton, etc., regions. On the lines of Baker, Jones produced his book *Agricultural Regions of South America* in 1928. Similarly, Taylor delineated agricultural regions of Australia in 1930. Another American geographer Valkenberg divided Asia into agricultural regions in 1931. It was Derwent Whittlesey who delineated the *Major Agricul-*

tural Regions of the Earth in 1936 Since Whittlesey's essay was published, there has been much discussion of the problems of agricultural typology and the allied problems of regionalization.

Table 1.1

Development of Agricultural Geography

Author	*Year*	*Contribution*
Young, A	1770	Environment and Cropping Patterns in England
Von Humboldt, A	1807	Land Use in Cuba and South America
Schwenz, J N	1816	Environment and Cropping Patterns in Germany
Von Thunen, J H	1826	Der Isolierte Start in Beziebung auf Ladwirtschaft und Nationalokonomie, Rostock
Engelbrecht, T H	1883	Crop Regions of North America
Krzymowski, R.	1911	Scientific Position of Agricultural Geography
Jonasson O	1926	Agricultural Regions of Europe
Baker, O E	1926	Agricultural Regions of North America
Jones, C F	1928	Agricultural Regions of South America
Taylor, G	1930	Agricultural Regions of Australia
Valkenberg	1931	Agricultural Regions of Asia
Whittlesey, D	1936	Major Agricultural Regions of the Earth
Stamp, L D	1948	Land of Britain Its Use and Misuse
Weaver, J C	1954	Crop Combinations in Middle West
Shafi M	1961	Land Utilization in Eastern Uttar Pradesh
Coppock, J T	1964	Agricultural Atlas of England, Wales and Scotland
Kostrowicki	1964	Agricultural Typology of the World
Grigg, D B	1969	Agricultural Systems of the World
Symon, L S	1970	Agricultural Geography
Morgan, W B and J R. Munton	1971	Agricultural Geography
Husain, M	1979	Agricultural Geography
Singh J, Dhillon S S	1990	Agricultural Geography

L.D Stamp prepared a comprehensive land use survey of Britain after the Second World War and produced his monumental work *Land in Britain Its Use and Misuse* Shafi produced the first land use study in the form of *Land Utilization in Eastern Uttar Pradesh* under

the able guidance of Stamp. Weaver applied an objective criterion in the delineation of *Crop Combination in Middle West* in 1954. It was in 1964 when Coppock prepared the *Agricultural Atlas of England, Wales and Scotland.* In 1964, the International Geographical Union (IGU) set up a Commission on Agricultural Typology, which has tried to establish uniform criteria by which farms should be classified, and to persuade the individual geographers to use these criteria in their works on different parts of the world. Kostrowicki, in 1964, published his leading essay *Agricultural Typology of the World.* The *Agricultural Systems of the World:An Evolutionary Approach* was published by D.B. Grigg in 1969. This book describes the chief characteristics of the major agricultural systems of the world and attempts some explanation of how they came into being While describing and explaining the agricultural systems, Grigg followed Whittlesey's classification of world agriculture In 1970 Symon published almost a comprehensive textbook in the form of *Agricultural Geography* for the graduate students. Morgan and Munton published *Agricultural Geography* in 1971 to cater to the need of graduate geography students. The *Agricultural Geography* by Husain (1979) has been widely accepted as textbook for higher level. The *Agricultural Geography* written by Singh and Dhillon (1990) is a useful textbook which has been prescribed in most of the Indian universities.

Agricultural geographers, before the 1950s, had been almost obsessively preoccupied with explanations for distribution patterns derived from study of physical environment alone Related studies of spatial science and economics were largely ignored. Prior to the Second World War there was scarcity of reliable agricultural data, especially on the developing countries. But, after the Second World War, a legion of literature has been produced in the Socialist and Third World countries. In 1974 Jasbir Singh published *An Agricultural Atlas of Haryana* in which he probed the physical, economic and cultural variables as the bases of farming and identified some ecological problems arising out of the existing land use practices Inspired by Shafi and Singh the younger generation of Indian geographers has been making useful contributions in the field of agricultural geography which vary from topical to regional and macro to micro level. Modern agricultural geography in which physical, sociocultural, eco-

nomic, institutional and infrastructural factors are taken into consideration for the description and explanation of agricultural phenomena is mainly a product of the post-Second World War period. For the interpretation of agricultural mosaic geographers are concentrating on the collection, processing and tabulation of primary and secondary data. The data thus processed is plotted on maps before their geographical interpretation is made. By applying sophisticated statistical and cartographic techniques, geographers are now increasingly concentrating on paradigms and models building for generalization and deduction In other words, there is more emphasis now on model building which is proving fruitful in the explanation of land use patterns and other agricultural phenomena. A systematic discussion on the theories and models of agriculture has been made in the following paras.

In order to understand the modern agricultural geography and its utility in the process of agricultural development planning it is imperative to discuss briefly the various methodologies adopted by geographers to examine the agricultural phenomena.

Approaches to Agricultural Geography

A legion of literature has been produced about the nature, methodology and approaches of agricultural geography. If one reviews the mounting literature on agricultural geography, two major approaches to the subject matter can be detected (Ilbery, 1979):

Empirical (Inductive) Approach

The empirical approach attempts to describe what actually exists in the agricultural landscape. It gives special privilege to empirical observations. According to empiricists, "the facts speak for themselves". In this approach explanation of the patterns is sought by inductive methods and generalizations are made on the basis of results from numerous studies. For example, for the delineation of crop combinations of a given region, crop land use data is gathered from the farms and villages over a period of time. This data is processed and plotted on maps and then an explanation of the combinations is made which ultimately lead to generalization and model building.

Normative (Deductive) Approach

The normative or deductive approach is more concerned with what the agricultural landscape should be like, given a certain set of assumptions. This approach leads to the derivation and testing of hypotheses and, theoretically, to the development of an ideal model of agricultural location. The model of von Thunen in which several assumptions, like isomorphic surface, economic farmer, isolated state, etc., have been made is based on deductive approach.

These two approaches have never really merged, reflecting both the complexities of the decision making process in agriculture and the different times at which each has been popular within geography. It is essentially from the normative (deductive) approach that models of agricultural location have emerged and once again model makers have operated along one of two lines, with the later developing out of dissatisfaction with the former.

Models of Agricultural Geography

Optimizer Models

Optimizer models are usually concerned with the notion of profit maximization. In such models, optimal land use patterns rest on the assumptions of (i) rationality of the farmer, (ii) complete knowledge, and (iii) an equal ability to use this knowledge. Such assumptions and requirements are unobtainable in reality and the approach has been criticized as unrealistic. In fact, there will be hardly any farmer who may be knowing about the weather especially precipitation that will prevail during the growing season of a crop or the full information about the quality of seeds and the demand of the produce. Consequently, this model fails to explain the ground reality of agricultural activities. It has been rightly said that farmers cannot make perfect economic decisions, except by chance, and instead react to perceived conditions within an environment of uncertainty. Owing to these weaknesses of the optimizer models, 'satisfaction' has been put forward as an alternative, leading to 'satisficer models'.

Satisficer Models

These models are more realistic and take farmers' motivations, aspirations and attitudes into account. These models include such items

as farmer's desire for leisure, a satisfactory income, at the expense of profit maximization. This approach developed out of two classic geographical studies by Wolpert (1964) in an analysis of Swedish farming and Harvey (1966) in an early review of theoretical development in agricultural geography, and led to the new behavioural element in the methodology of the subject.

Agricultural Processes and Phenomena: Modes of Explanation

As with normative and empirical approaches, there is a noticeable gap between these two groups of models and it would appear that even satisficer models are failing to explain the observed agricultural phenomena adequately. Despite these different approaches and the many methods available to the geographer, theoretical developments in agricultural geography have been slow. Indeed, it could be suggested that little real theoretical progress has been made since the pioneering work of von Thunen (1826). However, different modes of explanation have been adopted by geographers to explain the agricultural processes and phenomena over the earth surface. These modes of explanation are as under :

1. Environmental or deterministic approach
2. Commodity approach
3. Economic approach
4. Regional approach
5. Systematic approach
6. System analysis approach
7. Ecological approach
8. Behavioural approach
9. Humanistic approach

Environmental or Deterministic Approach

The view that the environment controls the course of human action is known as deterministic approach. The protagonists of this approach assume that elements of physical environment (terrain, slope, temperature, precipitation, drainage, soil, fauna and flora) act in a deterministic manner and control the cultivation of crops and all the deci-

sion making processes of the farmers about agricultural activities. It is a belief that variation in agricultural decision making around the world can be explained by differences in the physical environments. The essence of determinism is that the history, society, culture, economy, agriculture and geopolitics are exclusively controlled by the physical environment.

It has been advocated by the environmental determinists that the characters of all vegetation, plants and animals including man are the products of temperature, moisture and prevailing weather and geoclimatic conditions. It has been proved by the ecologists and agricultural scientists that every plant has a specific zero below which it cannot survive. There is also an optimum temperature in which the plant is at the greatest vigour. For each of the functions of vegetation like germination, foliation, blossoming or fructification a specific zero and optimum can be observed in temperature. The environmental determinists thus argued (Klages, 1942) that for any crop there are minimum requirements of moisture and temperature without which the crop will not grow. The cultivation of wheat in India may be taken as an example to explain this point. The ideal physical conditions for wheat crop are found in Punjab, Haryana and western Uttar Pradesh. Going away from the 'wheat heartland' the intensity of its cultivation steadily declines in all directions. In the north of Punjab, the winters are severe in Himachal Pradesh and Kashmir valley, in the south, the state of Rajasthan is arid with a high rate of evaporation, while east and southeastward (eastern Uttar Pradesh, Bihar, Madhya Pradesh) the geoclimatic and pedological conditions are less conducive for its cultivation.

Despite biotechnological advancements, most of the crops cannot be grown economically if the appropriate temperature conditions are not available. For example, the northern limit of rice is the mean annual isotherm of 15° C and during the transplantation and harvesting periods the mean daily temperature should remain over 25° C. Similarly, the northern limit of date-palm is the mean annual isotherm of 19° C, and grapes ripen only in those countries in which the mean temperature from April to October (in the northern hemisphere) exceeds 15° C. Maize and rice do not ripe if the mean daily temperature goes down below 10° C during their growth, blossoming

and fructification.

Since temperature is the major determinant in the distribution of crops. it is evident that their growth is essentially dependent on the total amount of insolation received during the life span of the crop. It is because of this factor that maize harvests within 80 days in the Sutlej-Ganga Plain and matures in about 110 days in Mussoorie, Shimla, Chamba, Bhadarwah and Kashmir hills. Interestingly enough maize is sown in some of the counties of Scotland (Ayreshire etc.), valleys in Alps, but it does not ripen even after ten months because of the low temperatures even during the summer season. Consequently, it is purely a fodder crop there. Similarly, the High Yielding Varieties (HYV) of rice which are matured and harvested within ninety days from the date of transplantation in the fertile plains of Tamil Nadu, Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal take about 120 days in the valleys of Kashmir, Chamba and Dehra Dun.

The rainfall regime and availability of moisture also influence the decision making process of the farmers about a crop to be sown. There are xerophilous (tolerant to drought) and hygrophytes (needing more moisture) crops It is because of this property of the plants that the crops which perform well in the wet climatic areas cannot be grown successfully in the arid and semiarid areas unless adequate arrangements for artificial irrigation to the crop are made. The districts of Amritsar, Faridkot and Firozpur in Punjab, and Ganganagar and Bikaner in Rajasthan, which receive less than 50 cm rainfall, have become the important producers of rice. In fact, rice performs well only if the average annual rainfall is over 100 cm. The farmers of these districts grow rice with the help of canal and tubewell irrigation. The excessive irrigation in Punjab, Haryana and the Indira Gandhi Canal catchment area of Rajasthan has affected adversely the soils which are becoming waterlogged, saline and alkaline. The underground watertable has been lowered and the farmers often complain that the soils are becoming increasingly hungry, needing more chemical fertilizers every year. Many of the waterlogged and saline and alkaline patches have lost their resilience characteristics.

Out of the physical determinants the impact of soils is also quite significant. The performance and yield of each crop varies with the variations in the physical and chemical properties of soils. For exam-

:, rice performs better in the clayey soil while wheat and sugarcane quire well drained alluvial soil. Saffron, a leading condiment, can-t be grown out of the *karewas* of Kashmir and Bhadarwah velleys &K).

Although the influence of physical elements is being increas-gly modified through improved technology, HYV, irrigation, fertil-ers and insecticides, yet the natural environment puts a limit be-nd which a crop cannot be grown successfully.

The environmental deterministic approach has been criticized on veral grounds. The main weakness of this approach is that it is ertly simplistic as it ignores the cultural factors and their influence agricultural activities. Moreover, similar geographical locations ay not necessarily result into similar cropping patterns. For exam-e, the Manchuria province of China and New England region of the ited States have almost similar locations and almost identical cli-atic conditions, yet their agricultural typologies differ from each ier.

Man with his technological advancement has successfully dif-sed crops in new areas away from their traditional regions. Rice, a op of wet regions of India (Assam, West Bengal, etc.), now has erged as the first ranking crop of *kharif* season in the districts of njab and Haryana. Similarly, wheat has been diffused in some of e districts of Maharashtra, Andhra Pradesh, Karnataka and West ngal. These illustrations clearly show that man is an active agent the ecosystem and has enormous capacity of transformation of ag-ultural landscape. He is growing several crops even in the harsh d adverse physical environmental conditions.

In brief, it may be said that elements of environment put a limit the cropping patterns and land use practices but farmers equipped th modern technology are almost free in their decision making out the crops to be sown. The influence of environment may be ormous in the regions of extreme climates (equatorial, hot deserts), impact on the agriculture of developed societies is however, quite significant.

mmodity Approach

e commodity approach of agricultural geography is based on the

axiom that "the whole is more than the aggregate of its parts". It focuses on the point that any phenomenon of agriculture should be examined and explained in totality and not in parts to ascertain the ground reality about the decision making process of the farmers. The main objective of the commodity approach is to make an indepth analysis of a particular phenomenon, say a crop. The approach may be explained with the help of an example. Suppose the geography of tea is to be discussed with commodity approach. In such study an attempt will be made to examine the environmental conditions (temperature, moisture, soil, tillage, etc.) required for its cultivation. Subsequently, the areal distribution, concentration, production, productivity, marketing, processing, distribution and consumption have to be discussed and explained.

The commodity approach is a colonial legacy. The geographers of Europe adopted this approach to ascertain the areas wherefrom the raw material may be obtained for their industries. During the second half of the nineteenth century and up to the First World War a number of monographs were produced in Europe about the geography of rubber, tea, coffee, cotton, jute, hemp, sugarcane and spices. The focus of this approach remained to identify the regions which are more efficient in the production of certain crops. In India, D.S. Sandhu (1977) produced a monumental work based on the commodity approach in the form of Geography of *Sugarcane Cultivation in Eastern Haryana*. This book gives a vivid description of the prevailing physical environmental conditions in the region and the cultural milieu of the area. The area under sugarcane, its yield per unit area, total production, marketing and processing have also been systematically examined

Though commodity approach provides useful information about the geoclimatic requirements of individual crops, it does not take into consideration the behavioural aspects of the farmers in their decision making process. The normative questions, such as values, motives, attitudes and beliefs of the farmers are ignored. Any study made with this approach gives only a parochial picture of geographical reality of an agricultural phenomenon.

Economic Approach

The economic approach developed as a categorical rejection of the

environmental deterministic approach. The economic approach assumes that the farmer who takes decision about agricultural activity and the sowing crops in a given season/year is a rational or economic person He has the full information about the elements of physical environment, the available technology and the demand of the commodities he produces. It is also assumed that the economic factors of market, production, transport and distribution costs operate on a group of homogeneous producers, who in turn react to them in a rational manner.

The protagonists of economic approach advocate that the relationships between physical environment and farmers are neither simple nor constant (Sayer, 1979). These relationships are governed by social and historical processes. The economic base or mode of production is seen as the key to understanding the complex web of interconnections involving the institutions, patterns of behaviour, beliefs, etc., of the farmers. The farmers consciously discard one crop and adopt a new one to optimize their profits. The higher agricultural returns as a result of new cropping pattern change the material and technological base of the farmers. In brief, this approach stresses on economic determinism which has been quite popular in the writings of geographers of the developed and socialist countries.

In India, a tangible change has occurred in the cropping patterns during the last three decades. For example, the cultivation of rice has become quite important in the relatively less rainfall recording areas of Punjab, Haryana and Rajasthan (Ganganagar district) while wheat has been diffused from Punjab up to Dimapur (Nagaland) in the east, Maharashtra and Karnataka in the south and Suru, Dras and Shyok valleys of Ladakh in the north. The cultivation of grapes in Sangli, Kolhapur and Satara districts of Maharashtra, pomegranates in the Talengana region of Andhra Pradesh, keenu orchards in Firozpur, Amritsar, Kapurthala and Gurdaspur districts of Punjab, the mint cultivation in Moradabad district of Uttar Pradesh, soyabean in the Malwa plateau of Madhya Pradesh and sunflower cultivation in the Sutlej-Ganga Plain have been diffused only during the last three decades. In fact, the cropping patterns and crop rotations in the greater parts of the Sutlej-Ganga Plain are no longer static The traditional rotation of crops has been discarded and the fallowing of land for the

recuperation of soil fertility has been given up. These changes in agricultural mosaics of India are the results of farmers rationality and their desire to optimize their benefits by producing more per unit area.

The economic approach has also been criticized on several counts. The main objections raised are against its assumptions of rationality of the farmers and their full knowledge of the environment, technology and forces of market. In reality, man does not behave always as an economic person. Many of the decisions are constrained by the availability of workforce, capital and costly inputs Despite fertile soil and suitable weather conditions some of the small farmers do not go for the cultivation of potatoes, vegetables and rice as these are labour intensive. Sometimes the disposal, marketing and storage facilities come in the way of adoption of a new crop. The farmers of Punjab and Haryana are not much interested in the cultivation of vegetables and fruits as the processing industries are very few and these are highly perishable commodities. Consequently, they are concentrating on the cultivation of rice (*kharif* season) and wheat (*rabi* season) crops which are highly soil exhaustive. The growers of these crops in areas of low rainfall argue that in the absence of elaborate marketing mechanism, rice and wheat they are more profitable as can be stored easily.

The assumption of full knowledge of the farmer about weather, inputs and market has also been criticized. In fact. the farmers of any part of the world are not in a position to acquire the full knowledge of the physical (weather etc.) and socioeconomic processes. In developing countries like India, agriculture is not even today adequately protected from the vagaries of monsoon. It is still, to a large extent, a gamble in the monsoons. Crops failure occurs at an interval of three to five years with monotonic regularity. In certain parts of the country (Rajasthan, Marathwada, Assam, Bihar) agriculture is almost annually vulnerable to natural havocs like drought and floods. The uncertainty factor has deprived farmers of confidence in their better future. Thus, the farmers of the developing countries are generally not economic rational persons. To them agriculture is not a business but a way of life, a mode of living and this philosophy guides their decision making process about cultivation of crops and allied activities.

The political climate and government policies also have a close bearing on the farming activities For example, the extension of terraced fields at the steep slopes in Japan is simply because of the scarcity of arable land partly as a result of the self-reliant policy in food of the government The cost of production of paddy in such fields is more than the output, yet the farmers being subsidized by the government are doing rice cultivation even on uneconomic tracts Similarly, the farmers of Saudi Arabia are growing wheat barley and vegetables in some of the *wadis* (oasis) and investing about $ 10 to get return equivalent to $ 1 Such decisions are not expected from the rational economic farmers but the government policies are in favour of self-sufficiency in the matter of food The economic approach thus does not explain completely the decision making process of the farmers and presents only a parochial picture of the ground reality

Regional Approach

The concept of 'region' developed in the eighteenth century is still a basic notion of geography Classically, region is a differentiated segment of the each surface or an area having homogeneity in physical and cultural characteristics As this phrasing suggests, the study of regions was for a long time closely identified with a definition of geography as the study of areal differentiation The concept of region is quite important in all the branches of the discipline including agricultural geography

It was Baker (1926) who strongly supported regional approach for the study of agricultural geography Subsequently, Valkenberg (1931), Whittlesey (1936), Weaver (1954), Coppock (1964) and Kostrowicki (1964) emphasized the importance of regional approach to the study of agricultural geography

In regional approach a country or an area is delineated into agricultural activity regions with the help of certain relevant agricultural indicators Later on the agricultural attributes of the delineated regions are examined and explained In regional approach, the micro regions constitute the meso regions which in turn become the components of macro region This exercise continues till the entire earth surface is covered

The main advantage of the regional approach lies in the fact that

it provides an organized, systematic and reliable explanation of the agricultural phenomena spatially arranged over the earth surface. For example, the delineation of crop concentration, crop combination, and agricultural productivity regions helps in understanding the attributes of agricultural of the given region and explains the decision making process of the farmers. An indepth understanding of such regions also helps in generalization and the formulation of sound strategies for agricultural planning and development. This approach goes a long way in removing the regional inequalities in the levels of production of different crops.

Systematic Approach

Systematic approach is also known as the 'general' or 'universal' approach. It was Varenius who divided the discipline of geography into general (systematic) and particular (regional) geography.

The systematic approach is concerned with the formulation of general laws, theories and generic concepts. It is in contrast to regional geography in which models are designed with the help of certain assumptions.

In this approach an agricultural phenomenon (crop etc.) is examined and explained at the world level and then some generalizations are made. The spatial distribution of wheat or rice in the different continents and the explanation of its concentration in certain areas of the world is an example of systematic approach. The systematic and regional approaches to agricultural geography are however not opposed but complementary to each other.

System Analysis Approach

The system analysis approach was adopted by Ludwig (1920) in biological sciences. According to James, a system may be defined as a unit (a person, an agriculture, an industry, a business, a state, etc.) which functions as a whole because of the interdependence of its parts. A system consists of a set of entities with specifications of the relationship between them and their environment.

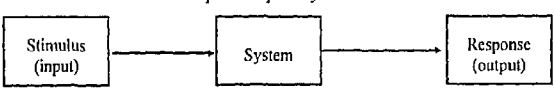
Agricultural geography deals with the complex relationships of physical environment, cultural milieu, and the agricultural phenomena. System analysis approach provides a framework to examine and explain the agricultural activities at the field, village, local, regional,

national and global levels. The complex entities and mosaic of agricultural activities can be understood with the help of this approach. It was because of this advantage that Berry and Chorley suggested system analysis as a vital tool for geographical understanding.

Each agricultural system has several elements (tenure, tillage, irrigation, biochemical, infrastructural and marketing). These elements have their reciprocal effect on each other. The behaviour of a system, therefore, has to do with flows, stimuli, and responses, inputs and outputs and alikes. The internal behaviour of a system and its transactions with environment can be examined. A study of the former amounts to a study of functional laws that connect behaviour in various parts of the system. Consider a system that has one or more of its elements related to some aspects of the environment. Suppose the environment goes under change (e.g., deforestation in Himalayas, canal irrigation in Jaisalmer, Bikaner, saline and alkaline formations in Punjab, reclamation of swampy land in Sunderban Delta, encroachment of agriculture on pastures, etc.), then at least one element in the system is affected and effects are transmitted throughout the system until all connected elements in the system are affected For example, if irrigation is being developed in an arid area, the people will shift from cattle rearing to cultivation of crops which in turn will affect the ecology, and the good agricultural production will provide more impetus to the farmers to use their arable resources more intensively. It will lead to a chain reaction in the system and both the ecology and society will be transformed. This constitutes a simple stimulus response or input-output system. This behaviour is described by the equations (deterministic or possibilistic) that connect the input with

Figure 1.2

Input-output System



the output (Fig. 1.2).

A system in which one or more of the functionally important variables are spatial, may be described as geographical system. Geographers are primarily interested in studying systems whose most

important functional variables are spatial circumstances, such as location, distance, extent, area, sprawl, density per unit area, etc

Though systems may be closed or open, in geography, they are generally open systems In an open system, the elements of other systems also influence the decision making processes of the farmers An indepth study and systematic analysis of an open system thus becomes quite a difficult task This point may be explained with the help of an example The valley of Kashmir, nestled in Himalayas and surrounded on all sides by high mountains, apparently gives the impression of a closed system Functionally, the reality is different Through the Banihal tunnel, the valley is well connected with the rest of the country and the air and telecommunication linkages also provide enormous social interaction between the Kashmir valley and the rest of the world It is because of these linkages that the saffron growers, dry fruits (almond, apricot, walnut) traders, apple orchard owners and carpet manufacturers are very well connected with the neighbouring and distant agiourban ecosystems of the country and the word The decision making process of the Kashmiri farmers is thus largely influenced by the elements of other systems too

Owing to its utility, the system approach has been engaging the attention of geographers For example, Chorely attempted to formulate thinking in geomorphology in terms of open system, Leopold and Langbein used entropy and steady state in the study of fluvial systems and Berry attempted to provide a basis for the study of 'cities as systems within systems of cities by the use of two concepts of organization and information in spatial form Recently, Wolderberg and Berry have used system concepts to analyze central place and river patterns while Curry has also attempted to analyze settlement locations in system framework Thus, the geographers who focus attention upon spatial organization invariably invoke systems as Haggett s account of locational analysis in human geography demonstrates

In geography static or adaptive systems can be constructed easily It is, however, difficult to make a geographical system dynamic for which we must combine time and space in the same model Space may be expressed in two dimensions by cartographical abstraction We may be able to present a satisfactory explanation for such a sys-

tem but it is very difficult to handle the third or the time dimension in the same model.

In the existing complex agricultural situation of the world an input-output ratio is to be determined by taking into consideration the relevant indicators from within and outside of the system. For example, agricultural productivity in a region is the function of geoclimatic, sociocultural and economic factors. The interrelationships between these determinants and their influence on the agricultural productivity can be understood by system analysis with the help of correlation and multivariate regression. For example, only by analyzing irrigation system, biochemical fertilizers system, and marketing and storage systems, etc., one may establish the causes of good or bad performance of a crop in a region.

System analysis has been criticized on the ground that it is intrinsically associated with empiricism and positivism (Husain, 1995). The normative questions like values, beliefs, attitudes, desires, hopes, fears, aesthetics, etc., are not been taken into account by system analysts. Consequently, it gives only a partial and less reliable picture of the geographical reality.

Ecological Approach

Ecological approach deals with the interrelationships of plants and animals (including man) with each other as well as with the elements of their nonliving environment This approach focuses on the interrelatedness of the biotic and abiotic environment and takes ecosystem as the home of man.

The followers of ecological approach emphasize on the point that similar geoclimatic conditions lead to the similar agricultural activities. With the change in geoclimatic and pedological conditions, a change occurs in plants. Under the changed temperature and moisture regimes the plants (crops) have to struggle for their survival. This process has been termed as 'natural selection'. Those plants which survived were better fitted to the environment than competitors. Relatively superior adaptation increase; relatively inferior ones are steadily eliminated. Thus, the main focus of ecologists is on the study of ecological conditions that promote or discourage the individual organism (crop) and communities of organisms (crops asso-

ciation) in relation to their habitat.

The domestication of plants, their diffusion pattern and disappearance from some of the genecentres may be explained with the help of ecological approach. For example, during the neolithic period, about 10000 BP (before present), Southwest Asia was the region in which wheat and barley were domesticated. But this region is no longer the main producer of these crops. The decline in wheat and barley cultivation in Southwest Asia may be explained ecologically. Over the period of last millennium the climate, especially the rainfall regime, has changed. Consequently, some of the plants could not adapt to this change and could not survive. Their place has been taken by other plants who could adjust in the semiarid and arid conditions of the region.

In the opinion of ecologists, the farmers adopt the agricultural activities which may adjust well in the existing temperature and rainfall regimes. Thus, environment influences the decision of farmers and they in turn modify the environment by their agricultural practices. In fact, scientific and technological advancements have made man as the most important factor of environmental change.

The main criticism against the ecological approach is its overemphasis on ecological processes and 'natural selection'. The role of man (farmer) is underestimated in this approach. In reality man equipped with advance biotechnological knowledge is doing many practices against the prevailing ecological conditions. Transplantation of rice in Punjab and Haryana in the schorching heat of the first weak of June when the daily maximum and minimum temperatures record 45° C and 35° C respectively and the relative humidity dwindles to only 11 per cent seems to be against all the ecological principles but the farmers are doing this with the help of canal and tubewell irrigation. Man is not an innovator, he is an imitator and adopter also. These qualities of human being help him in taking some decisions about agricultural activities which may be against the ecological settings and environmental conditions.

Behavioural Approach

As a reaction to quantification, the behavioural approach has been adopted by some of the geographers to explain the agricultural activi-

ties and the decision making process of the farmers at the various levels. It became more popular after 1960 in geography.

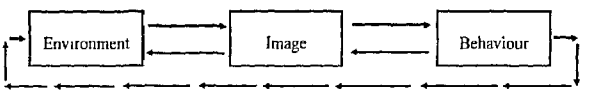
The essence of behavioural approach is that the way in which farmers behave is mediated by their understanding of the environment in which they live or with which they are confronted with. Behavioural geographers recognize that man shapes as well as responds to his environment and that man and environment are dynamically interrelated.

The behaviouralists argued that environment has a dual character, i.e., (i) as an objective environment—the world of actuality; and (ii) as a behavioural environment—the world of the mind.

In the real world, a farmer takes decision on the basis of his per-

Figure 1.3

A Conventional Model of Man and Environment Relationship



ceived environment. The decision making process has been explained in Figure 1.3.

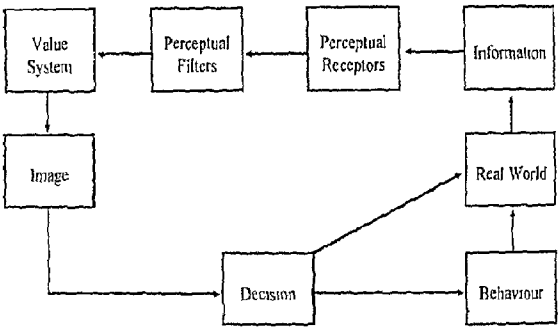
The difference between the perceived and the real environment was vividly made clear by Koffka (1935) in an illusion to the medieval Swiss tale about a winter travel. "On a winter evening amidst a driving snowstorm a man on a horse back arrived at an inn, happy to have reached after hours of riding over the winter swept plain on which the blanket of snow had covered all paths and landmarks. The landlord who came to the door viewed the stranger with surprise and asked from whence he came ? The man pointed in a direction away from the inn, where upon the landlord in a tone of awe and wonder said : Do you know that you have ridden across the Great Lake Constance? At which the rider dropped stone dead at his feet "

This illustration shows the difference between the 'objective environment' of the ice covered lake and the rider's 'behavioural environment' of a wind swept plain. The traveller perceived the lake as a plain and took a decision to travel across the lake as if it were dry-

Figure 1.4

Environmental Perception and Behaviour

(after Downs· 1970a, 85)



land. He would have acted otherwise had he but known.

Apart from differentiating between the objective (real) environment and the perceived (mental map), the behaviouralists do not recognize man as a 'rational or economic person' who always tries to optimize his profit. According to them, agricultural decisions, most of the times, are based on behaviour (values and attitudes) rather than on the economic benefits. In the tradition bound societies of the developing countries like that of India 'agriculture is a mode of life' and not 'agribusiness' It is because of the socioreligious values that tobacco cultivation is not being done by the Sikhs, piggery is forbidden among Muslims and dairying is a taboo among the Khasis of Meghalaya and Lushais of Mizoram.

It is also emphasized by the protagonists of behaviouralism that the same environment (resource) has different meanings to people of different socio-economic backgrounds and technology. For example, a tract of fertile land in the Sutlej-Ganga Plain has different meanings for the cultivators of different communities and farmers having different sizes of holdings. Living in the same village a Jat farmer prefers to sow rice and wheat, a Saini goes for vegetable cultivation and a Gujjar and Gada concentrate for the cultivation of cereals, sugarcane and fodder crops. The same tract of land has different meanings for a small cultivator with plough and a large scale holding farmer who operates with tractor and modern technology.

The behavioural approach is a useful one as it helps in understanding the decision making process of the farmers who are largely guided by their social values in the decision making process. There are several weaknesses in this approach also. The main weaknesses of behavioural approach are that it lacks in synthesis of empirical findings, poor communication, inadvertent duplication and conflicting terminology. Its terminology and concepts remain loosely defined and poorly integrated owing to the unsystematically organized theoretical base.

Another weakness of the approach is that most of the data in behavioural geography is generated in laboratories by doing experiments on animals and the results thus obtained are applied directly to human behaviour. Koestler (1975) pointed to the danger of this strategy, in that behaviouralism has replaced the anthropomorphic fallacy—ascribing to animals human faculties and sentiments—with the opposite fallacy, denying man faculties not found in lower animals; it has substituted for the erstwhile anthropomorphic view of the rat, a ratomorphic view of man.

Moreover, in the absence of general theories and models the behavioural approach been considered as merely descriptive and not explanatory in nature. As a result agricultural geography becomes like systematic inventory and description.

In brief, the general criticism of the behavioural approach is that one can never know for sure whether one has actually succeeded in providing true explanation as the values of individual farmer and farmers community vary in space and time. This allegation seems to be genuine but on a closer examination it loses much of its force as an argument for not taking the approach seriously. Although one can never know with certainty that a behavioural explanation of agricultural phenomena is true, the same objection is applicable to all empirical, interpretive and theoretical works. For example, even the theoretical physicist can never be certain of his theories. Indeed, the history of natural science is largely a history of abandoned theories. Yet progress has been made, because with the failure of old theories, new more powerful ones have emerged In social sciences a behaviouralistic interpretation will also be challenged in terms of new evidence and new argument. In the process of interpretation of old and

new, a more accurate and powerful account of "what really happened" will gradually emerge.

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2 Origin of Agriculture

The science or art of cultivating soil, growing and harvesting of crops, domestication of animals and raising of livestock is known as agriculture. In its broadest modern sense the word 'agriculture' includes not only the domestication of plants and animals useful to man, but also many of the operations involved in marketing them.

Man made snail speed progress during the early stages of history as the environment, he existed in, was harsh and he was not materially and technologically equipped to cope with the severity of surroundings. In fact, primitive man subsisted by gathering nuts, grains, roots and fruits, and catching animals, birds and fish for meat. Thus, he learned to harvest before he discovered how to plant.

The legends of the beginning of cultivation cover a wide range of speculation, including divine teaching by the gods. Many gods have been worshiped for their power over the weather and over the growth of plant and animal life. Isis in Egypt, Demeter in Greece, Ceres in Rome, Mikael in Palestine, and Varun in India are only a few examples of the gods revered by ancient people.

When, where and how agricultural developed has been a topic of considerable research during the last century. There is a unanimity on the point that agriculture has no single, simple origin. Traditionally, the emergence of agriculture has been regarded as revolutionary, but the evidence from archaeological sites prove that it developed and spread gradually in an evolutionary process. In fact, many plants and

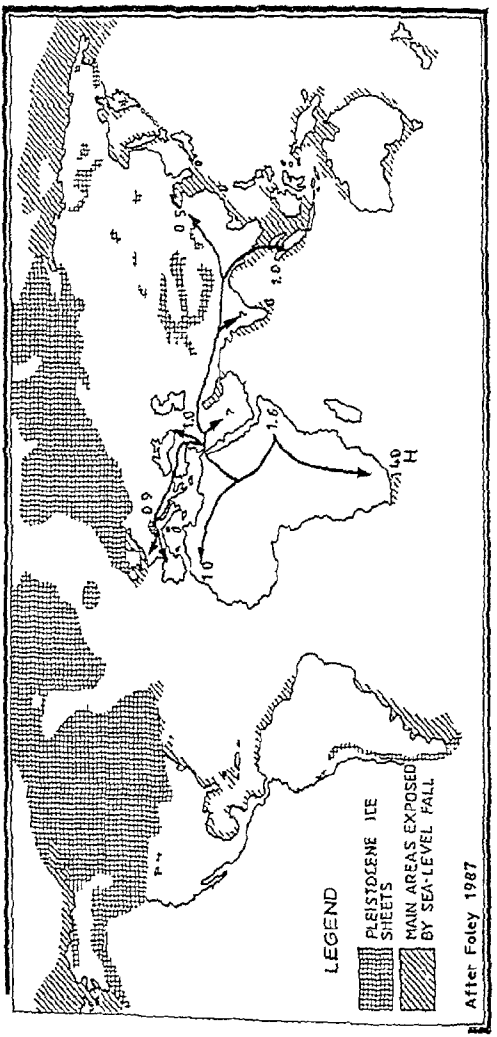


Figure 2.1
Dispersal of Early Hominids

animals have been domesticated at different times in numerous places

For large part of human history hunting and gathering have dominated food procurement strategies as they still do in many of the primitive tribes of the world The homonids, and their ape-like ancestors, must have relied on local sources of food that they selectively chose (Fig 2 1) The evidence from the palaeolithic, mesolithic and neolithic periods obtained from the excavation of ancient sites prove this point substantially

Domestication of plants and animals or the origin of agriculture is quite recent in the annals of mankind The more recent investigations show that agriculture began around 10000 years BP (before present) or 8000 BC during the Sumerian times in Southwest Asia According to Zohary (1986) excavations at a number of early neolithic villages in Near East (Southwest Asia), e g , Jericho, Bethasaida, Hebron, Ramad, Haran, Tell-Aswad, Jarmo, Ali-Kosh, etc , indicate that by 9000 BP cereal crops were being sown and harvested (Fig 2 2)

There are compelling reasons to prove that einkorn wheat (triticum monococcum), emmer wheat (triticum turgidum) and wild barley (hardeum spontaneum) were cultivated around 7000 BC at Ali-Kosh on the border of Iraq and Iran (Fig 2 3) There are archaeological evidences which show that beans (phyaseolus), peas (pisum) bottle gourds (lagenaria siceraria), and water chestnut (trapa) might have been grown at the Spirit Cave in northern Thailand around 7000 BC In the Americas, pumpkin (cucurbitta) and gourds (lagenaria) are known to have been domesticated in the Tehuacan valley in the northeast Mexico about 6000 BC

Most probably cultivation of crops and domestication of animals were started by societies that had already achieved a degree of sedentary life by intensive gathering and collecting of wild foods From observation of modern tribal people it can be speculated that many individuals in these primitive societies had a sustained practical interest in wild plants and detailed knowledge of their properties Under the prevailing circumstances of the neolithic period they undoubtedly understood that seeds could reproduce plants They also realized that if one cleared out vegetation from around a plant it

Figure 2.2
The Distribution of Wild-Emkorn, Wild-Emmer and Wild-Barely

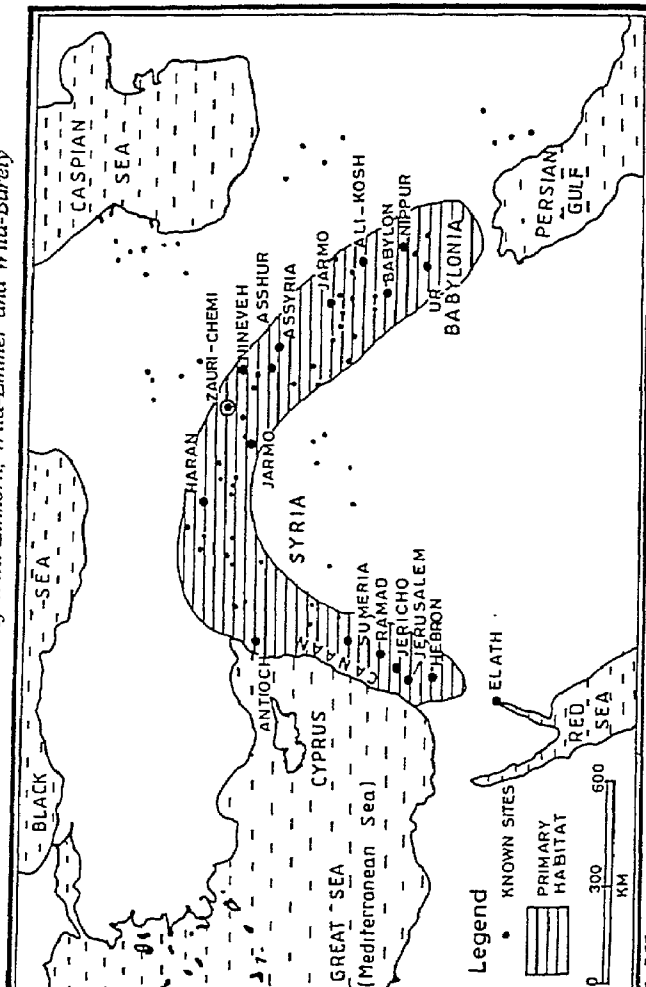
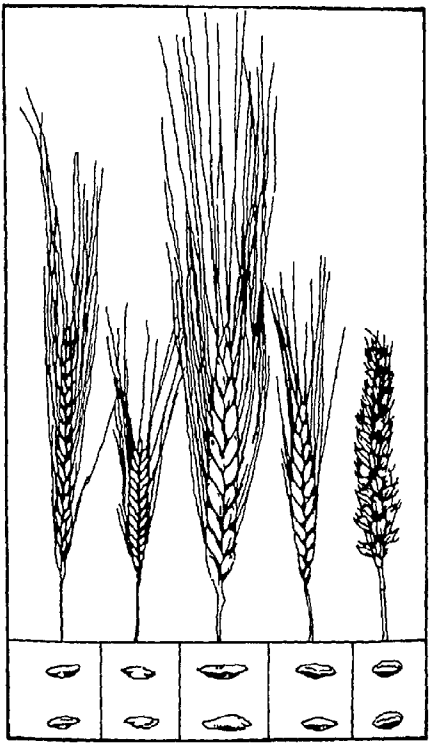


Figure 2.3
Wild and Cultivated Wheats



Wild and Cultivated Wheats (Left to Right) wild Einkorn Einkorn Wild Emmer Emmer Bread Wheat Scales Ears, about 1/2 Grains about 9/10
From E C Curwen and G Hatt Plough and Pasture (Copyright 1953) Murnat Publications Inc

would grow better Moreover, there are strong reasons to believe that women who used to stay back at the camping site while the menfolk was on hunting missions, was the real pioneer of plant domestication In fact, even today, the primitive tribal people have a double econ-

omy system, in which men are usually hunters and women are food gatherers, and so perhaps women as gatherers with greater interest and knowledge of plants might have done the domestication of plants.

With the increase in population in the sedentary communities there was more demand for food. The development of agriculture was an intensification by man of his food extractive processes from the wild ecosystems. More food could be obtained from a given area of land by encouraging plant and animal species found useful and discouraging others. This provided food for an increased population and gave better opportunity for settled life Durable houses as well as tools such as pestles, mortars and grindstones came into more general use. Techniques of food storage in pit silos and granaries also grew.

Evidences from archaeological sites and radio-carbon dating reveal that most probably earlier cultivation of crops was started on the foothills of upland areas of easily worked soil and not in the valleys because development of agriculture in the valley implies water control which need more skill and relatively more advance stage of technological development. This hypothesis about the beginning of agriculture in the forested foothills was put forward by Sauer—the American biographer. Sauer (1952), in his hypothesis about the origin and development of agriculture, propounded that :

1. Agriculture did not originate in communities desperately in short supply of food, but among communities where there was sufficiency of food resulting into relative freedom from want and need.
2. The hearths of domestication are to be sought in regions of marked diversity of plants and animals.
3. The primitive agriculture did not origin in the large river valleys, subject to the lengthy floods and requiring protective dams, drainage or irrigation, but in moist hill lands.
4. The agriculture began in forested lands which had soft soil easy to dig.
5. The pioneers of agriculture had previously required special skills but the hunters would be least inclined towards the domestication of plants.

6 The founders of agriculture were sedentary folks, because growing of crops requires constant attention and supervision and unless guarded properly, the crop will be lost

Major Genecentres

A significant contribution to the modern knowledge of the main centres of origin of cultivated plants has been made by Vavilov (1949)—a Russian biogeographer His researches, based on field investigations and archaeological findings, indicate the main areas of domestication of plants and animals These areas form the primary breeding culture Accumulated evidence since Vavilov's time has suggested the following eight major genecentres A genecentre is a geographical locale of wild ancestors of the modern cultivated plants (Fig 2 4)

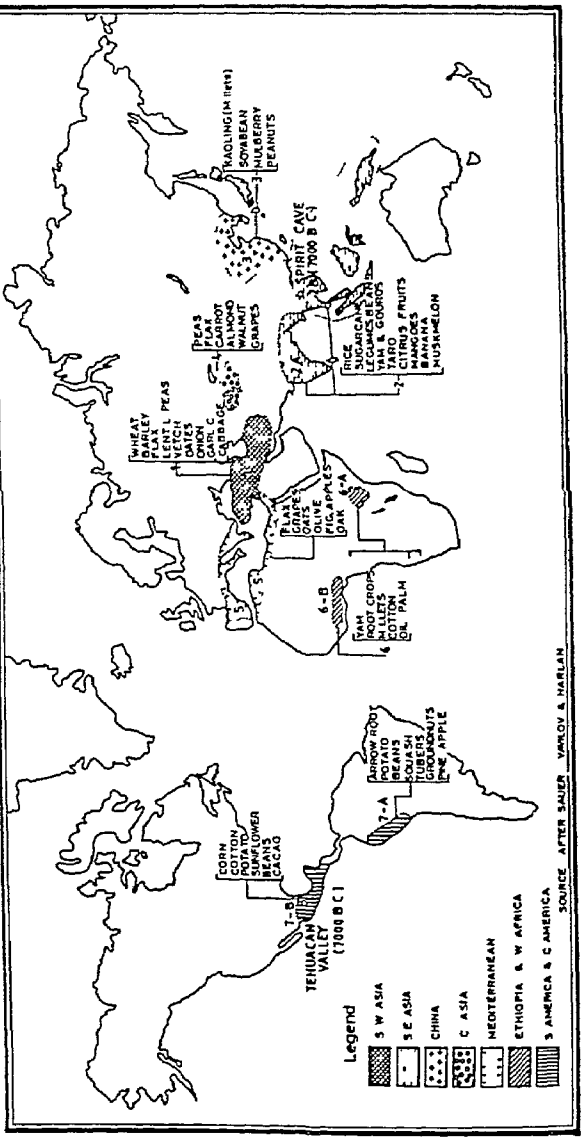
The Southwest Asian Genecentre

The Southwest Asian Genecentre stretches over Asia Minor, Levant coast, Anatolia (Turkey), Palestine, Israel, Jordon, Lebnon, Syria, Iran, Iraq, Afghanistan, Arabian peninsula, Egypt, Cyprus, Crete and Greece The archaeological and paleobotanical evidences show that plant domestication in Southwest Asia occurred between 10000 BP and 8000 BP As stated earlier, excavations at a number of early neolithic villages (Jericho, Ramad, Bethasaida, Haran) indicate that by 9000 BP cereal crops were being sown and harvested The dominant cereals were emmer and einkorn wheat, spelt and barley—all of which are the members of the grass (gramineae) family The most common pulses which were domesticated in this region include lentil (lens culinaris) and peas (pisum sativum) Moreover, chickpea, broadbean, melon and several vegetables were also part of arable economy Flax was also domesticated in this region as it is also found being deposited in the neolithic deposits

The experts of history of agriculture have unanimity of opinion about Southwest Asia as the oldest and leading genecentre in the world They also opine that by about 10000 BC people who relied upon hunting and gathering were reaping wild barley and wild wheat About 6000 BC, there seem to have been both farming villages and nomadic camping sites, probably with trade and other concentrations in them It has been estimated that Ur, a large town of Mesopotamia covering about 50 acres (20 hectares) within a cultivated tract, there

Figure 2.4

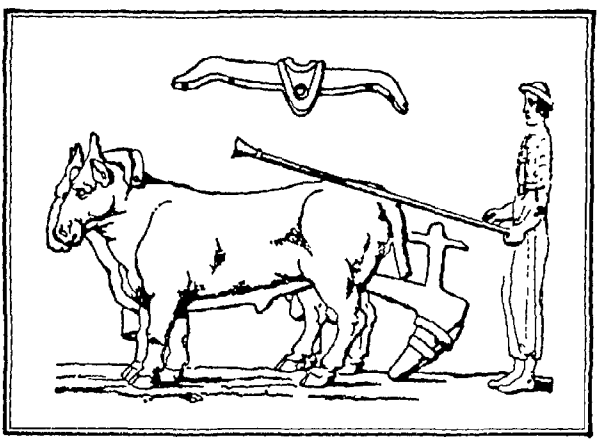
Genecentres·Major Areas of Plant Domestication



were 10,000 animals confined in sheepfolds and stables. The workforce included store house recorders, work foremen, harvest supervisors and labourers (Fig.2.2).

In the early Sumerian dynastic phase (3000 BC) barley was the main crop, but wheat, flax, dates, apples, plums, grapes and vegetables were also grown. The land used to be ploughed by teams of oxen and the crops were harvested with sickle in the spring (Fig. 2.5).

Figure 2.5
Etruscan Plougman (First Century B C)



Development of irrigation in the Nile valley came as a major agriculture development. Irrigation gave more stability to the agrarian-cum-pastoral economy of Egypt. There are ample evidences which suggest that the water of Nile river was carefully controlled and canal distributaries were dug to provide irrigation to the cultivated crops whenever needed.

Apart from Palestine, Canaan, Sumeria and Egypt there are evidences which show the development of settled communities living in villages in Anatolia (Turkey), Syria, valleys of Tigris and Eupharetes, and the Zagros mountains of Iraq and Iran. These village com-

munities were growing wheat, barley, flax, peas and lentil by 6000 BC. Subsequently, the number of domesticated plants got increased in these areas. Some of the important vegetables like cabbage, leek, lettuce, onion, garlic and beans also have their origin in the Southwest Asian Genecentre

According to Zohary (1986), the wild ancestors of most of these early crops exhibited a relatively limited distribution. Wild emmer wheat and chickpea are endemic to Southwest Asia, while wild einkorn wheat, barley, vetch and peas have a wider distribution in the region. Subsequently, these crops were diffused in Europe, and other parts of Asia and Northern Africa.

The earliest farmers of Southwest Asia had reaping knives, sickles, grain storing pits, mortars, pestles and grinding stones. They probably also had digging sticks and later primitive hoes, made at first from wood and later from stones. The most important change was the slow adoption of ox-drawn plough. This plough invented by the Sumerians and Anatolians was made of wood called 'Ards' which did little more than scratch the surface of the earth. By 4000 BC this plough (Ard) was diffused in Mesopotamia and the Nile valley. In Egypt, water lifting devices such as shaduf, water wheel and carads were started by 1000 BC. From here these technological developments spread to the neighbouring areas of the east and the west.

The Southeast Asian Genecentre

The Southeast Asian Genecentre spread over India, Pakistan, Bangladesh, Sri Lanka, Myanmar (Burma), Thailand, Laos, Combodia, Vietnam (Indo-China), Malaysia, Indonesia and Philippines (Fig.2.4).

A large number of plants like rice (oryza sativa), sugarcane, legumes, sugarpalm, coconut, bamboo, taro, yam, turian, tropical fruits, mango and banana were domesticated in this region. Moreover, cucumber, eggplant, cowpea also had their origin in this genecentre.

According to Zohary and Hopf (1988) rice is a southeast Asiatic element but because of the ease with which its wild relatives hybridize, the exact centre of its domestication has not yet been determined. The earliest finds of rice that can be positively identified as domesticated are from sites in India and Pakistan, dated about 4500 BP.

In the opinion of Sauer, the Southeast Asian Genecentre is one of the oldest genecentres of the world. The earliest archaeological evidence available from the Spirit Cave of Thailand shows that legumes were domesticated in this region around 9000 BC (Fig.2.4). The farming system was found in the valley floors and deltas. From Thailand it spread towards Malaysian, Indonesian and Polynesian islands. Very little is known about the technology and methods of farming in the Southeast Asian Genecentre. It is likely to have been primitive, relaying upon stone axes, digging sticks and fire. Besides vegeculture (protection of plants) and cultivation of crops, the people of Southeast Asia mainly relied on hunting, gathering and fishing for much of their supplies.

The China-Japan Genecentre

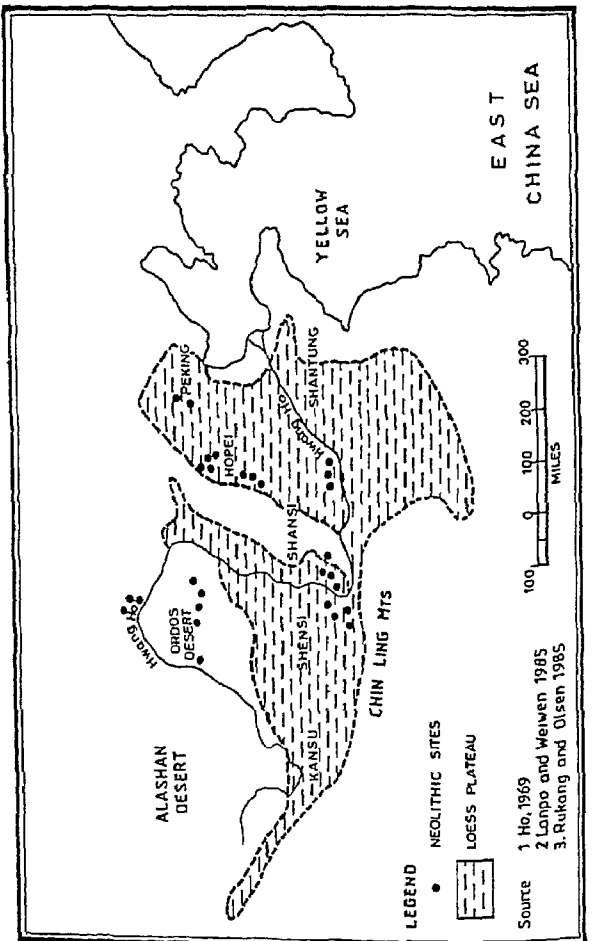
Archaeological information about this genecentre is comparatively scanty. The first known farmers in northern China lived in the Loess uplands of the Middle Hwang Ho and the Wei Ho between 6000 BC and and 5000 BC. These farmers domesticated soyabean, kaoliang (sorghum), millet, corn, sweet potatoes, barley, peanuts, fruits and vegetables. Cotton, tobacco, sugarcane, tea and sericulture (silkworm) have been the important cash crops (Fig.2.6). From the Loess plateau, agriculture spread towards Manchuria, Korea and Japan in the north and towards the Yangtze Kiang valley in the south. There are reasons to believe that in China, most probably, wheat, barley, sheep, goats and cattle were acquired from the SouthWest Asia, whilst soyabean, kaoliang, mulberry and pig were locally domesticated (Fig.2.6).

It is also most likely that the practice of irrigation spread to China from Babylonia. The Chinese are known to have had irrigation before 2200 BC. The main implements were digging sticks, hoes, spades and mortars. The plough was also acquired from Southwest Asia For the maintenance of soil fertility a number of practices were adopted in China by 5000 BC. The main aim of the farmers was most probably conservation of moisture rather than irrigation.

The Central Asian Genecentre

The Central Asian Genecentre of Vavilov includes the region sprawling over Afghanistan, Tajkistan, Uzbekistan, Kazakistan, Kirigizis-

Figure 2.6
The Origin of Agriculture in N. China:Neolithic Period



tan, Turkmenistan and the area lying to west of the Tien Shan. To the east of the Caspian Sea in Turkmenistan an agricultural community grew between 4000 BC and 3000 BC. These farmers were doing cultivation of crops with the help of irrigation. They adopted mixed agriculture, based on a combination of crops and livestock which characterized to that of Mesopotamia. Peas, flax, alfafa, almond, walnut, pistachio, grapes, melons, carrots, onion, garlic, radish, spinach, berries and numerous fruits were domesticated in this genecentre (Fig 2.4).

The Mediterranean Genecentre

The Mediterranean Genecentre extends from the Iberian peninsula (Portugal and Spain) in the west to Greece in the east. It also includes the coastal strips of Africa along the Mediterranean Sea. Domestication of plants and animals in this genecentre occurred mainly in the coastal areas of Spain, France, Italy, Albania, Bosnia, Serbia, Croatia (Yugoslavia), Crete and Cyprus (Fig.2.4).

Primarily it is the genecentre of oats, flax, olive, figs, vines, rutabagas, lupines, oak, and lavender. By 4000 BC, the crops of the Mediterranean region much of its distinctive crops, e.g., olive, vine and fig had been domesticated in the eastern parts of the Mediterranean lands. Vegetables which have their origin in this genecentre are atrichokas, asparagus, cabbage, celery, chicory, olive, cress, endive, leek, lettuce, onion, garlic, parsnip, peas, and beans.

The African Genecentre

The Nile valley (Egypt), being close to the Southwest Asian Genecentre, derived agriculture from this region. The archaeological evidences obtained from the site of al-Fayyum (Lower Nile Basin) show that sheep, goats, and swine and cultivated wheat, barley, cotton and flax were cultivated in this region in 5000 BC. The flax was woven into linen and cotton used for the preparation of cloth. In this dry climate, village silos consisted of pits lined with coiled basketry, and crops were harvested with reaping knives slotted with sharp flints. The farming communities of Egypt started agriculture initially above the flood plains as in the valley of the Nile river regular inundation was the main hindrance.

The Egyptian farmers also kept deer, gazelles, sheep, goats and

livestock. The wetter areas were exploited by domesticated ducks and geese. The marshes, swamps, wasteland and stubbles were grazed by numerous herds of cattle (black, piebald and white) sheep with kempy (coarse) coats, goats and pigs.

The origin of agriculture to the south of Sahara is still a matter of controversy. In Ethiopia and the west coast of Africa, vegeculture most probably developed along the margins of tropical forests and savanna lands where climate was warm and wet. The major plants domesticated in tropical Africa are Yam (indigenous to West Africa), and oil-palm trees. West Africa, in fact, still remains as one of the few areas of the world where root crops form a major part of agricultural economy. Tropical Africa is also the primary genecentre of sorghum, African rice, castor beans, cotton, water-melon, cowpea, coffee, oil-palm, and kolanut.

The South American Genecentre

This genecentre extends over Peru, Brazil, Bolivia, Equador, Argentina and Chile. It is conjectured that in South America, domestication of plants in the from of vegeculture started sometimes between 7000 BC and 3000 BC. Here, the first domesticated plants of tuberous species like the manioc, arrowroots, waternuts, sweet pototoes, yautia, sorrel, ulluco, ochira, beans, tuber and squash were vegetatively propagated. These species are rich in starch. Later peanuts, groundnuts, and pineapple were also domesticated in this genecentre. In Bolivia, Chile. Equador and Peru, vegetables like limabeans, potato, pumpkin and tomato were domesticated. Axe and digging sticks were the main equipments of the prehistoric farming societies of the South America. Slash and burn, irrigation, terracing, and the use of llama dung for manure were practised. The guanaco, ancestor of llama and alpaca was domesticated in this region around 2500 BC.

The Central American Genecentre

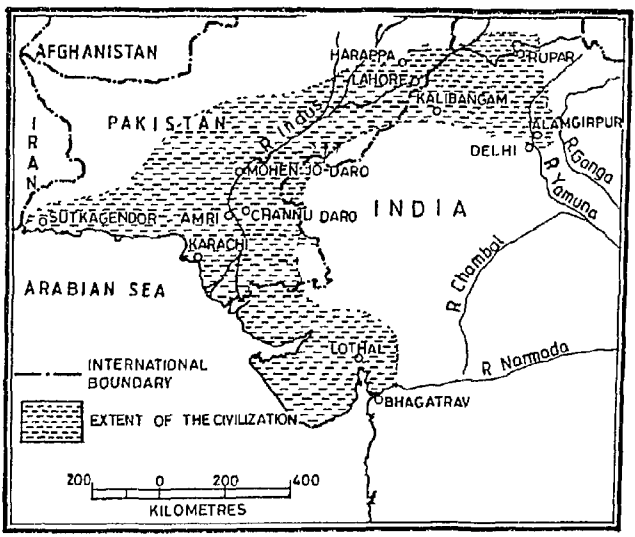
This genecentre spreads over the area of Mexico, Guatemala, Costa Rica, Honduras. Nicaragua, El-Salvador and Panama. Available evidence seems to indicate that, in spite of the early domestication of some plants, village life did not begin to develop in this region until 3500 BC. The process of agricultural development was, therefore, rather slow, occurring in widely dispersed centres. Corn (maize), ca-

cao, tomatoes, avocados, potatoes, kidneybean, zapotes, pumpkin and cotton were domesticated in this region It is also the homeland of red pepper, bean, sunflower and tobacco. In this region, the land was cleared by chopping and burning and the seeds were sown with the aid of fire-hardened digging sticks. Crops were stored in pits or granaries.

Apart from the genecentres discussed, some of the experts consider the Indus valley as separate genecentre (Fig.2 7). The most important plant domesticated in the Indian subcontinent was rice (oryza sativa), the staple food of South Asia and Southeast Asia. Sugarcane, varieties of legumes and mango are also native to the subcontinent of India. The excavations at Mohenjodaro and Harappa (Indus valley), Lothal on the Gulf of Cambay provide adequate evidences which show that the farmers of these regions were using sophisticated agri-

Figure 2.7

Subcontinent of India:Regions of Domestication of Plants Animals 2000-3000 B C



Source Based on Survey of India Map

cultural and pastoral technology as early as 3000 BC Irrigation to the crops was also a common practice in several suitable locations of the Indus valley

Table 2.1

Regions of Origin and Approximate Dates for Some of the Most Common Domestic Plants

Plants Species	*Region of Origin*	*Approximate Date in Thousand Years BP*
Emmer wheat	Near East (Southwest Asia)	9-10
Einkorn wheat	Near East (Southwest Asia)	9 5 8 5
Barley	Near East (Southwest Asia)	9 5 8 5
Pea	Near East (Southwest Asia)	9 5 8 5
Lentil	Near East (Southwest Asia)	9 5 8 5
Vetch	Near East (Southwest Asia)	9 5-8 5
Flax	Near East (Southwest Asia)	9 5-8 5
Naked wheat	Near East (Southwest Asia)	9 5 8 5
Rice	Southeast Asia	7-5
Sugarcane	Southeast Asia	7-5
Sorghum and mulbery	North China	Korea and Japan
Soyabean	North China	7-5
Almond, walnut, melon	Central Asia	6 5
Olive fig, vine	Mediterranean Europe	6-5
Sorghum and cotton	Africa	6-5
Cucubita pepo	Tropical America	9 8
Capsicaum maize (corn)	Tropical America	8 5-7 5
Common bean, cotton arrow-root, groundnut, tomato	Tropical America	7 7
Lima bean	Tropical America	7 7

Source Based Harlan, 1986, S J M Davis, 1987 Vavilov, N I, 1949, and Sauer C O, 1952

The primitive communities of the neolithic period domesticated plants for food, legumes, tubers, fruits, fibres and luxury crops. A classification of the plants cultivated in the early parts of human history has been given in Table 2 2

Table 2.2

Categories of Crops Cultivated During the Prehistoric Period

Food Crops	*Legumes*	*Roots/Tubers*	*Fruits*	*Fibres*	*Luxury*
Wheat	Peas	Turnips	Nuts	Flax	Cocoa
Barley	Beans	Carrots	Apples	Cotton	Tea
Rice	Lentils	Garlic	Figs	Hemp	Opium
Maize	-	Potatoes	Oranges	-	Tobacco
Millets	-	-	Dates	-	-

Source Vavilov and Perpillou

As discussed in the preceding paras the entrance of mankind from hunting and gathering culture to agriculture was not radical but gradual and evolutionary. The Figure 2.8 shows the evolutionary stages of man's cultural development during the palaeolithic period to the Bronze Age, while Table 2.3 gives an idea about the type of economy and culture of those periods.

Table 2.3

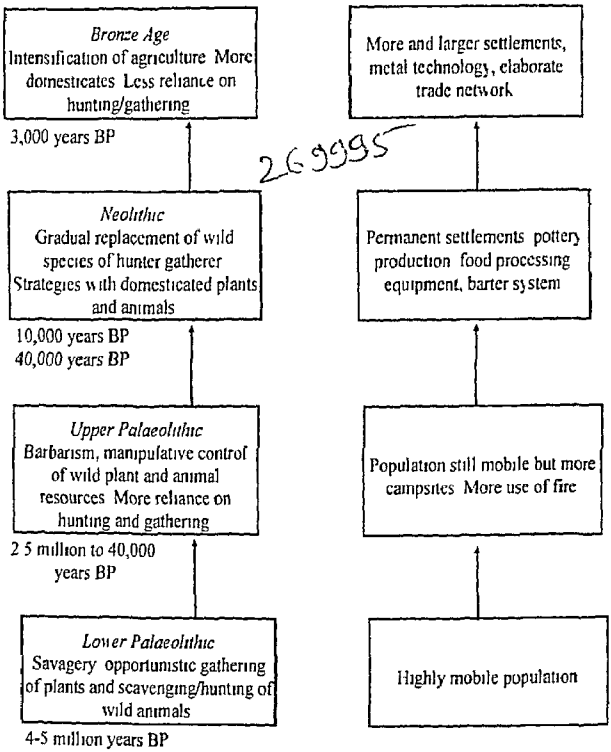
Changes in Food Procuring Strategies

5000-3700 BP	More productive agriculture and herding economy	Development of copper culture, wider range of pottery styles Increased population
6000-5000 BP	Increasing concentration on agriculture and harding as hunting diminished in importance Cattle and pigs domesticated	Pottery making began use of plough
7600-6000 BP	Domestication of sheep, goat, expansion in range of cultivated crops	Increase in settlement size More varied artefacts
8500-7600 BP	Exploitation of cattle, pigs, sheep, goats, wheat, barley, peas, lentil cultivated	Village development at Jericho, barter began, burial of dead
10000-8500 BP	Hunter/gathering economy with more intense use of animals Planting and harvesting of cereals and possibly pulses	Large camp sites increase in population
18000-10000 BP	Mobile hunters/gatherers No evidence for plant use	Dispersed population with small camp sites

Source Based on Moore, 1985

Figure 2.8

The Transition from Hunting and Gathering to Permanent Agriculture



Source Modified by the author after A M Mannion 1991

Domestication of Animals

The actual method by which animals were deliberately made to serve human needs can be stated only in terms of reasonable conjectures. Many prehistorians now believe that man lived in a symbiotic relationship with herding animals in the Pleistocene Age They also opine that the transition to 'domestication' took place in several parts of the world. Some of the experts suggest that the wild-horned ancestors of modern cattle called 'Auroch' was tamed by neolithic man Many anthropologists believe that animals were not initially domes-

ticated for economic reasons. Sauer (1952) suggested a ceremonial or religious basis for domestication while some others consider that the wild beast grew fat on the stubble of early grain plots and the discarded husk, and increasingly became dependent on man's farming activity. To some others stock herding arose from hunting and especially from capture of young animals which were driven off to the rock, enclosed valleys or desert oases where escape was impossible. There is a widespread and understandable idea that hunters killed adult animals, took their young ones to their habitats where children and womenfolk liked to fondle with them rather than kill them. Some of the tribal women of Tukano, Parakana, Kareen, Akrora and Kayapo from tropical America, and Dayak (Kalimantan), Kedang (Papua), Tsembaga (Papua New Guinea) and Polynesian tribes still nurse animals who have lost their mothers.

The propensity of women and children to keep pets has been suggested as the most probable spur to domestication. In fact, infant capture is the most direct and efficient mode of taming the wild animals. Darwin observed that primitive peoples in all parts of the world have easily succeeded in taming and rearing wild animals, and this provides an indirect evidence. However, Sauer reports that there are still some tribes in tropical America and Southeast Asia whose women suckle pups, lambs, pigs and kids. Domestication of one mammalian form would facilitate the domestication of additional ones with lactating animals replacing the human nurse. In this manner, Reed (1964) suggests that once sheep and goats had become domesticated, milk would have been available for orphaned calves and colts, thus making the domestication of larger species possible.

Archaeological data concerning domestication has been limited and difficult to interpret. The available direct and indirect evidences from archaeological sites are limited for a sound generalization. The indirect evidences such as animal dung and ash from fires may occasionally shed light on the question of domestication of animals. Anthropologists are coming to agree that the neolithic initiation and domestication and the subsequent food producing revolution added new dimension to man's biological and cultural existence, and was a necessary prelude to urban civilization.

Presumably man recognized that some animals and plants were

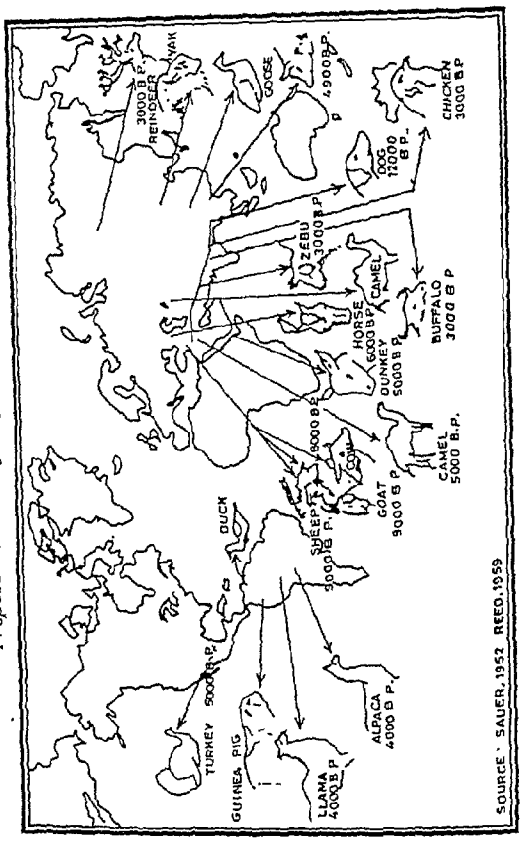


Figure 2.9
Proposed Centres of Major Domesticated Farms

more useful than others as sources of food. Moreover, it was preferable to ensure an adequate proximal food supply rather than have to engage in relatively haphazard foraging hunting. Traditionally, like plants, Southwest Asia has been regarded as the region in which animals were domesticated first in the world. In the opinion of Harlan (1986) domestication of animals occurred in other genecentres also at different times in the neolithic period.

The oldest animal of domestic status for which there is actual evidence seems to be dog. The ancestor of dog was the wolf which originated around 10000 BP in Southwest Asia.

Contrary to this there are some experts who opine that sheep was the first to be domesticated. The sheep which has descended from the wild sheep (ovis orientalis) was found in the mountains of Iraq, Iran and Turkey. It is believed that sheep was domesticated around 12000-9000 BP at Zauri Chemi in Iraq (Fig.2.9). At this site roughly 60 per cent of the sheep bones were of yearling. Somewhat later around 9000 BP, domestic goat, the descendant from capra-hircusaegagrus was also found in the same region. The goat seems to have been the first domestic food animal to have become widespread in Mesopotamia, Eygpt, Africa, Asia and Europe. About 7000 BP the domestic pig was introduced at Jarmo (Mesopotamia). The appearance of domestic cattle as per archaeological evidence occurred around 8000 BP at Tepe-Sabz in south Iran and Bananhill in Iraq. At this period ox-horns were in general use at Catal-Huyuk (central Turkey) in religious shrines as yet there is no evidence to show that they were obtained from domestic animals (Figs.2.9-2.11).

The horse appears to have been domesticated in Russia and Central Asia around 6000 BP and fragmentary evidence suggests that it was at about this time that camel was domesticated in Arabia. The ass or donkey appears to have originated in Egypt around 5000 BP. The four major food animals together with wheat and barley formed the basic economic complex of the Southwest Asia. In about 3000 BP, buffalo and chicken were domesticated in South Asia. The reindeer and yak were tamed in the north and east of Altai Highlands in about 3000 BP. The transport animals appear to have been domesticated generally later than food animals. Zebu, resembling the ox, was tamed in the Indus valley and Iran around 5000 BP. In South Amer-

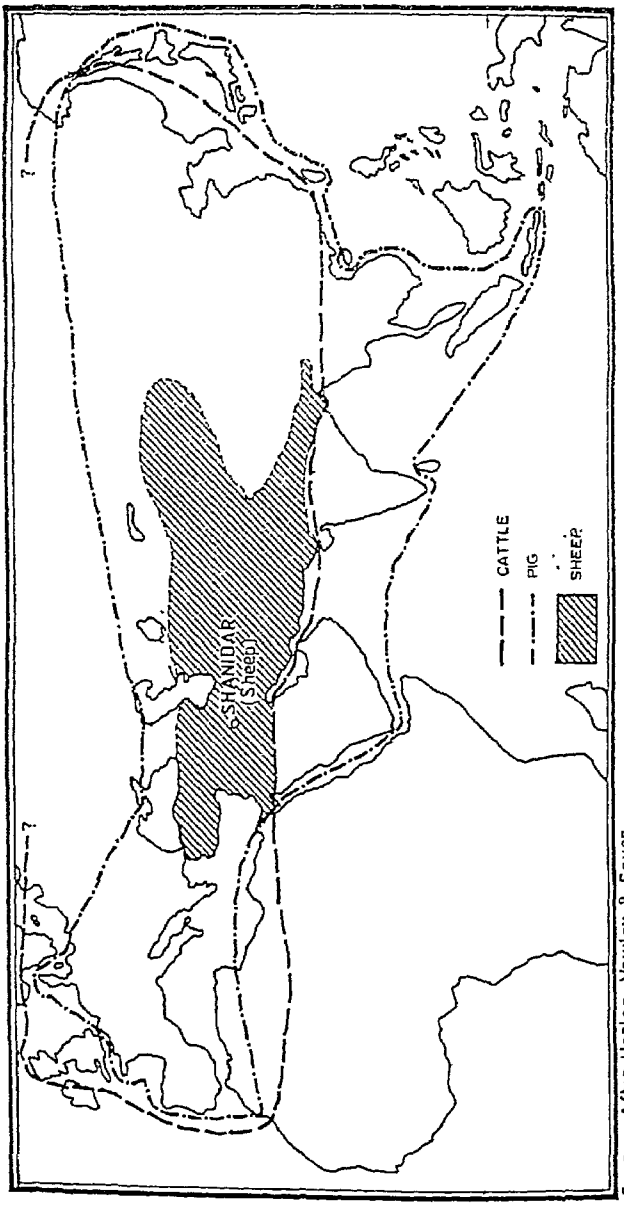
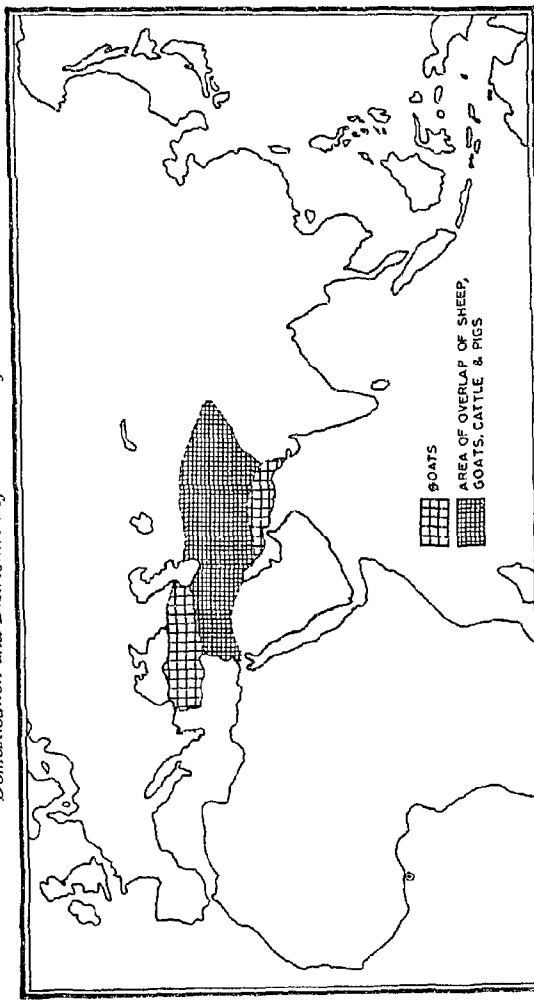


Figure 2.10
Domestication and Distribution of Ancestors of Cattle, Pigs and Sheep

Source. After Harlan, Vavilov & Sauer

Figure 2.11
Domestication and Distribution of Ancestors of Domestic Animals



Source: After Harlan, Vavilov and Sauer

ica, llama, alpaca and guinea pig were tamed, while Turkey bird was domesticated in Mexico and Central America.

Dogs probably accompanied hunters and helped them in their hunt of wild animals and beasts. There are reasons to believe that dogs also guarded the human settlement and the camping sites and at the same time they were eaten by men. Sheep and goats were also eaten in the initial stages of domestication. But later the quantities of milk production and wool made man aware of their economic value and they were spared from being killed.

In brief, the well documented and most extensive centre of animal domestication was the fertile crescent of the Southwest Asia extending from Iran to Jordan and Palestine. It was the centre of domestication of herd animals (sheep, goats, cattle and swine) in association of seed farming. In areas, peripheral to the Near East (Southwest Asia) Zebu cattle and donkey were domesticated. From Southwest Asia these cattle got diffused and dispersed to the other parts of the old world (Fig. 2.11).

The regions of origin and the approximate dates for some of the most common domesticated animals have been given in Table 2.4.

Table 2.4

Regions of Origin and Approximate Dates for Some of the Most Common Domesticated Animals

Animal Species	*Region of Origin*	*Approximate Date in Thousand BP*
Dog	Near East (Southwest Asia)	12
Sheep	Near East (SouthwestAsia)	12-9
Goat	Near East (Southwest Asia)	9
Cattle	Near East (Southwest Asia)	8
Pig	Near East (Southwest Asia)	7
Horse	Southern Russia (Central Asia)	6
Llama	Andean Puna	6
Alpaca	Andean Puna	6
Camel	Arabian Peninsula (Southwest Asia)	5
Buffalo	South Asia	3
Chicken	India,Burma	3
Turkey	Mexico	3
Reindeer	Siberia	3

Source Based Harlan, 1986; Davis, S J M , 1987; Vavilov, N I , 1949; Sauer, C O , 1952, West and Zhou, 1988

The Diffusion of Cultivation of Crops and Spread of Pastoralism

The available evidences from the different archaeological sites present a hazy picture of the beginning of agriculture and diffusion of crops. The story of domestication of animals is also identical. In fact, it is difficult to answer the question of how the ideas relating to agriculture got diffused. Necessity, for whatever reason, and inventiveness probably both played a part in the origin and spread of agriculture. There is a legion of hypotheses about the spread of agriculture and expansion of pastoralism in the prehistoric period. Some of the important hypotheses about the origin of agriculture have been presented briefly in the following paras.

Stimulus Diffusion and Migration Hypothesis

According to the stimulus diffusion theory the spread of agriculture may be effected by either stimulus diffusion involving exchange of ideas or by migration in which people move into new areas taking with them already developed agricultural practices and tools. The most well documented example of agricultural diffusion is that which occurred as agricultural practices spread outward from Southwest Asia. According to Zohary (1986) various combinations of crops that originated in the Near East (Southwest Asia) formed the basis for agricultural system in Europe, the Nile valley, Central Asia, the Indus valley and the Gangetic plain. Moreover, the establishment of cropping systems and crop combinations in these regions was relatively rapid.

It may be seen from Figures 2.12 to 2.16 that the cultivation of wheat, barley, pulses and flax appeared in Greece and Crete by 8000 BP and by 7000 BP it has spread to the Danube, the Nile valley, the Caspian Sea coast and to the Indus valley (Pakistan). By 5500 BP the cultivation of crop was started as far as Britain and Sweden. The stimulus diffusion theory supports the point that the new crops gradually replaced the old crops and transformed the indigenous natural ecosystems.

This theory has, however, been criticized as to many of the experts of agricultural history, change in climatic conditions induce change in the cropping patterns. Since the various plants perform differently at different temperatures, the new plants might have replaced

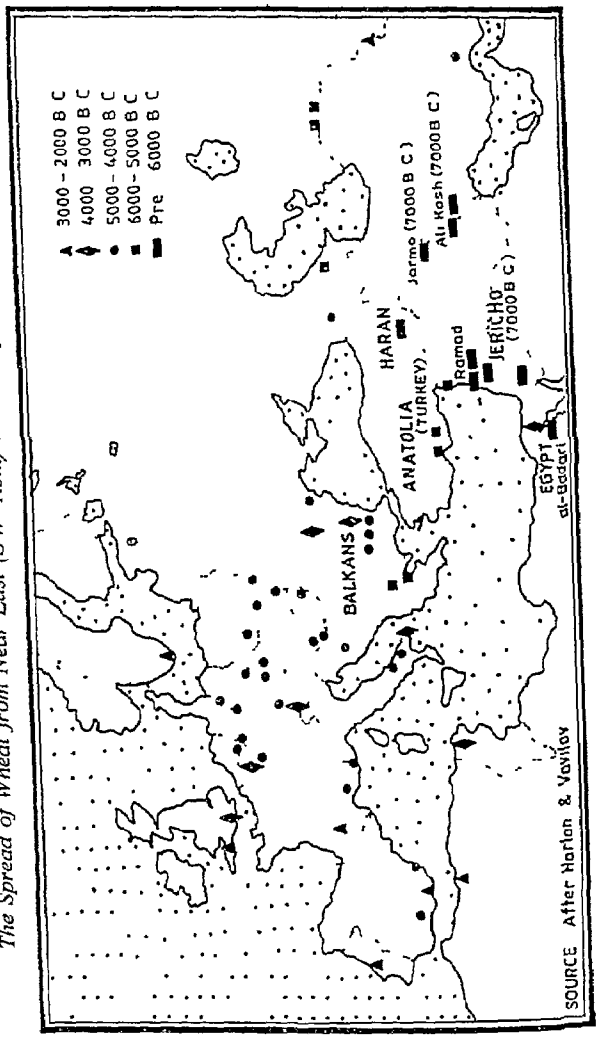


Figure 2.12
The Spread of Wheat from Near East (S W Asia) into Europe, Asia, and Nile Basin

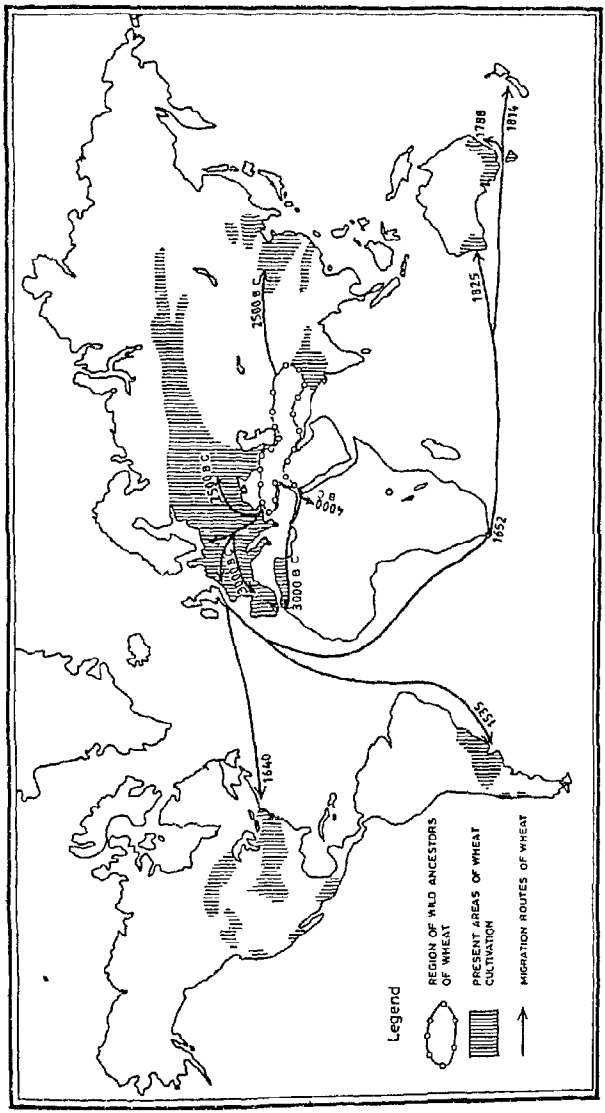


Figure 2.13
The Dispersion of Wheat

the old indigenous plants and crops. The technological advancement and cultural evolution also motivate the people to go for new crops and to adopt new agricultural systems.

Changing Climate Hypothesis

Climate changes in space and time. According to Barkar (1985) change in climate led to the development of agriculture. The nomadic hunters and food gatherers migrated from the relatively more cold, warm and wet regions to the areas of mild temperatures and temperate climates. In areas of mild climates having great diversity of plants, they camped for longer times for their sustenance. In the process they identified the useful plants, protected them and started their harvesting and cultivation.

This theory has also been criticized on more than one counts. The change of climate during the palaeolithic period was not substantial to transform the species of plants and trees and to modify the natural ecosystems. The migration of people and diffusion of ideas from one genecentre to another, therefore, seems to be more responsible for the diffusion of agricultural innovations in the new areas. The migrants carried the seeds, tools and technology to the places of their destinations. The exchange of ideas among the people of different regions acquainted them about the crops and the mode of their production. Owing to these criticism this hypothesis could gain very little support and popularity. There is also a possibility that burning of forests by wildfire might have killed the wild animals and destroyed the forests from where they used to gather their food. Burning in particular may have encouraged the spread of open habitat species like the grasses which provided the progenitors of emmer and einkorn wheat and barley. In consequence, the utilization of acron may have led to the exploitation, and ultimately the domestication, of plants such as members of the grasses and pulses families. The fire affected tracts provide an opportunity to the hunters and gatherers to think and sow the seeds of more food value. The shifting cultivators in the different tribal areas still practise the 'slash and burn' agriculture.

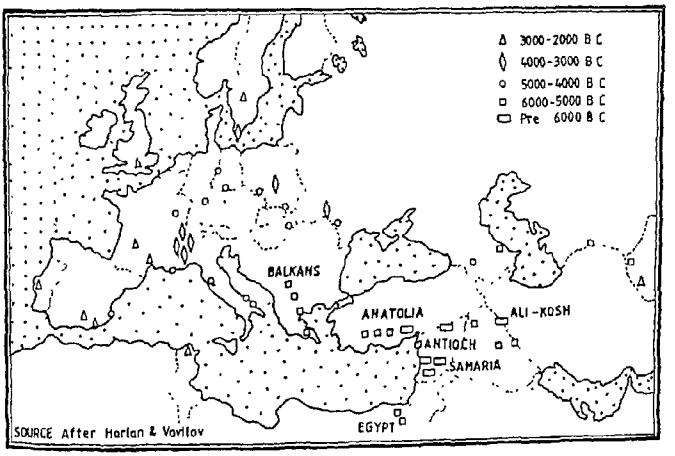
Rubbish Heap Hypothesis

Hawkes (1969) suggested the 'rubbish and heap' hypothesis. This

hypothesis implicates both plants and animals in a symbiotic relationship. Humans sought out plants with a good food reserve, like that of acrons (wheat and barley) and when these declined, they sought out grasses and pulses with equally good food reserves Such plants were reciprocally encouraged by the higher nutrient levels of nitrates and phosphates that probably typified camp sites and which could not survive in woodland shade.

Figure 2.14

The Spread of Barley from Near East (S.W Asia) into Europe, Asia and Nile Basin



Symbiosis between plants, animals and human groups may thus have led to the replacement of natural ecosystem components by domesticated species As a result, pastoral and arable agricultural systems emerged from natural ecosystems and subsequently intensified The selection of particular plants and animals by humans conferred advantages not enjoyed by any other species and led to the emergence of human groups as controller of environment. Through the ages this has become more sophisticated and not always to the advantage of human groups. The ecological factors may well have in-

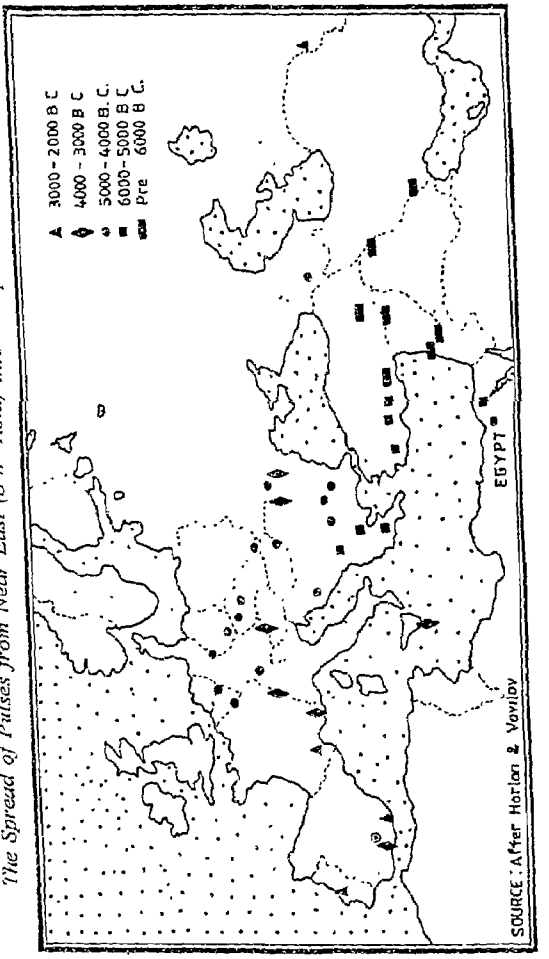


Figure 2.15

The Spread of Pulses from Near East (S W Asia) into Europe, Asia and Nile Basin

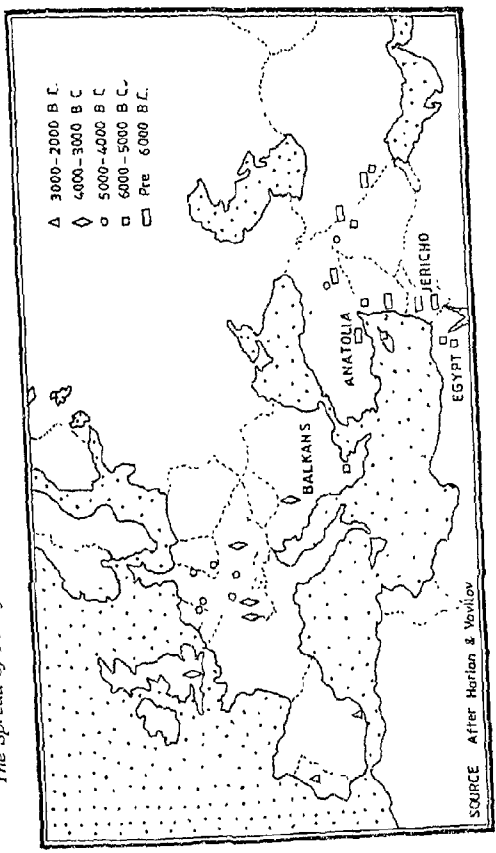


Figure 2.16
The Spread of Flax from Near East (S.W. Asia) into Europe, Asia and Nile Basin

fluenced the development of early hominids, but by 10000 BP humans were beginning to turn the tables Having already learnt to exploit ecosystem resources in as well organized hunters and gatherers, humans began to manipulate the genetic resource base via plant and animal breeding that led to the initiation and development of cultivation of crops and domestication of animals

The rubbish and heap hypothesis though explains the process of domestication of plants and animals, it does not give adequate weightage to the diffusion processes The direct exchange of ideas of the migratory hunters and gatherers may have stimulated the people of different areas, adjacent to the genecentres, to adopt the new technique of food production by domestication of plants and animals The change in temperature and moisture regimes also seems to be a vital factor to motivate the primitive hunters to start agriculture near the suitable camping sites

Diffusion of Crops During the Prehistoric Period

The preceding discussion reveals that plants of different species were domesticated in different genecentres during the neolithic period Their dispersal and diffusion in the neighbouring and distant areas was very slow during the early stages of human civilization

The Southwest Asia Crescent was probably the oldest and major centre of domestication of plants and animals It was from here that the cereals like wheat and barley travelled across the Mediterranean Sea to the basin of the Danube river From the Danube basin, agriculture spread towards the Baltic Sea and the North Sea in about 3000 BC Cultivation of crops was started for the first time in the plain of Ukraine (north of Black Sea) and the plain of Moscow around 2500 BC Farming from the Danube basin spread towards France, Germany, Holland, Spain and Portugal between 4000 BC and 3000 BC Archaeological evidences show that farming in the northern coastal plains of Africa called al-Mughreb (present Libya, Tunisia, Algeria and Morocco) was diffused from the Southwest Asian Genecentre through the Nile basin in about 4000 BC Agriculture from the crescent of the Southwest Asia spread in the east at a later period, but there are ample evidences to show that the agriculture of wheat and barley reached the northern border of Iran and the present Azerbaijan by 3000 BC The slow diffusion of wheat, barley and flax towards

the east may be attributed to the difficult mountainous terrain, barren and dry plateaus and the hot and dry uninhabited deserts between the Zagros and the Hindukush mountains. These physical barriers may have created obstacles in the movement of less equipped nomadic communities of the Southwest Asia (Figs. 2.12-2.13).

The earliest evidence of domestication of plants and animals in the subcontinent of India lies in its northwestern parts in the hills of Baluchistan and the Indus valley. There are anthropo-archaeological evidences which depict that in about 3500 BC there were farming communities in the hills facing the Indus valley, stretching between Zhob valley in the north to the Makran coast in the south. The farmers of this region used to grow club wheat (hard variety of wheat), kept sheep, goats, zebu, cattle and possibly constructed dams across the seasonal streams with stonewails to collect water in reservoirs and to use that for irrigation of crops at the time of demand. By 3000 BC, the farmers had settled in the plains of the lower Indus and started growing wheat, barley, pulses, flax, vegetables and green fodder crops.

The Mohenjodaro and Harappa civilization in the Indus valley emerged as a result of these farming communities. The Indus valley civilization was well spread over in a significantly larger region stretching from the Himalayan foothills in the north, Yamuna river in the east, Narmada river in the south and the Makran coast in the west (Fig.2.7). But most of the settlements of this civilization were on the banks of the Indus river and its tributaries. The largest known settlements are of Mohenjodaro on the lower reaches of the Indus and Harappa, about 670 kms (400 miles) to the north of Mohenjodaro on the bank of the Ravi river. The crops and cattle in the Indus valley were diffused mainly from Southwest Asia, though there had been some native crops like legumes and sugarcane. The main crops grown by the farmers of Indus valley were wheat, barley, sugarcane, peas, gram and dates. Cotton was diffused here around 3000 BC. Ragi and *bajra*, indigenous to Africa, were cultivated in south India in about 1500 BC. These crops, most probably arrived in India from Africa through the land route of Southwest Asia.

The spread of agriculture in the Ganga valley seems to have been much slower than in the peninsular India. Waves of invading Indo-

Aryan tribes presumably destroyed the Harappan cities and pe trated deep into Hindustan proper. With the Aryans came the hor coinage, Brahmi script and the whole corpus of Vedic literature. 1100 BC, the Gangetic farmers were equipped with plough and i axes. It may have been the dense forest and stiff soil cover which layed settlement in the Gangetic plains of India.

Apparently, rice played an important role in growth of popu tion and new rural settlements. They had spread eastward to Ganga delta by the seventh century BC.

In the Vedic literature (C 1000-500 BC), there are repeated ref ences to iron. Cultivation of a wide range of cereals, vegetables a fruits, meat and milk products were part of the diet, animal h bandry was important. The soil was ploughed several times. Se were broadcast. Fallowing and certain sequence of cropping w recommended. Cowdung provided the manure

As discussed in the genecentre of China, the first known e dence of agriculture is found in the loess uplands of the mid Hwang Ho in the northern parts of the country. Most probably far ing in this region was started around 6000 BC. Sorghum, millets a soyabean were the main crops cultivated by them (Fig.2.6). Th probably adopted shifting cultivation. These farmers later expanc towards Korea, Manchuria and Japan in the north and the Yangi Kiang valley in the south. Southern China had received rice, bana yam, sugarcane and squash from the Southeast Asian Genecent Presumably, grape-vine, sheep, goat and cattle were acquired China from Southwest Asia and Central Asia while pig was loca domesticated. The main implements were fire, digging stick, boe a spades.

The oldest archaeological evidence available from the Sp Caves of Thailand dates back about 7000 BC. Cultivation of r (oryza sativa) is commonly held to be derived from the two w varieties (oryza perrennis and oryza spontanea) which were found the marshy lands of India, low-lying areas of Philippines and co tries of Southeast Asia. Rice, thus, could have been domestica somewhere in this area. Rice from Southeast Asia spread to so China and Malaysia. The development of wet rice and transplan tion came much later. Historically, shifting cultivation has been

tive to all the countries and still survives in almost all the hilly tracts of Southeast Asia.

The beginning of agriculture in Africa, south of Sahara, is less clear. As discussed, under the Vavilov's genecentre, there were two independent plant domestication centres—one in the western Sudan and the other in Ethiopia. Some anthropologists opine that agriculture reached Africa, south of Ghana, only through the Nile basin and the al-Maghreb (northern and western coasts of Africa). There are reasons to believe that during the palaeolithic and neolithic periods Sahara was relatively more wet and was occupied by nomadic herders who may have practised some sort of agriculture Wheat and barley would have proved unsuitable in the summer rainfall areas of Sudan region and thus local plants such as pearl millet, finger millet, sorghum and root crops would have been domesticated. In the equatorial region, plough, however, did not reach until the nineteenth century.

Man reached the America across the Bering Strait before plant and animal domestication had appeared in the old world, and, therefore, agriculture in America is an independent development. Crops like corn (maize) cacao, sunflower, squash, beans, manioc, potatoes and groundnut were domesticated in America. Digging stick was the main farming equipment and plough was introduced in by the Europeans in the beginning of the sixteenth century. In South America, Peru and its neighbouring regions domesticated arrowroots, pineapple, squash, beans, potatoes, tomatoes, chillies, groundnuts and numerous tubers.

Spread of Crops During the Medieval Period

At the beginning of the Christian era there had been considerable interchange of plants between South Asia, Europe, Africa, India, China and Southeast Asia.

Crop farming and domestication of animals were well established in western Europe by Roman times. In the Roman empire, olive groves and vineyards were permanent, grain and pulses were annual. The crop and fallow practice was common. Soils to be sown were judged by colour, taste, smell, adhesion to the fingers when rubbed. Wheat and barley were sown in autumn and harvested in

spring season. Later on, the Arabs who had been active leaders in the Arabian Sea and Indian Ocean helped in the migration of crops and cereals from one region to another. The Arabs carried wheat, barley, rice, cotton, sugarcane, flax, peas and beans from Mesopotamia to North and West Africa and the Iberian peninsula (Spain and Portugal). They also introduced rice, citrus fruits, mango, coconut, cucumber and banana and several other indigenous plants from Southeast Asia to East African countries in the eighth and ninth centuries. The traders of Indonesia, Malaysia and Thailand crossed the Indian Ocean and reached Malagasy (Madagascar) where they brought rice, banana, taro and yam. Moreover, the Arab traders diffused wheat, barley, linseed, sesamum, flax and peas in China and its neighbouring countries.

During the period of 'Great Age of Discovery', i.e., thirteenth to seventeenth centuries, the European navigators, especially those from Spain, Portugal, Italy, Holland, France, Britain, and Scandinavian countries discovered sea routes to Southeast Asia and Far East. They also discovered the 'New World' (North and South America). Vasco da Gama reached India via the Cape of Good Hope in 1498, Columbus discovered America in 1492 and Magellan circumnavigated the world in 1521. These navigators helped in the diffusion of American crops into Asia, Europe and vice versa. It was during this period that more complex cropping patterns came into existence in all the agricultural regions of the world.

Spread of Crops During the Modern Period

From the viewpoint of diffusion of crops, the close of the Great Age of Discovery may be taken as the beginning of the modern period. A brief account of diffusion of crops during the modern period in different continents has been presented in the following paras.

Europe

Most of the crops cultivated in Europe by 1500 AD were diffused mainly from the Southwest Asia. Owing to the prevailing climatic conditions and primitive technology these crops remained mainly confined to the Mediterranean region, Balkans, Danube valley and the lowlying regions of Europe including the Ukrainian plain. After the Great Age of Discovery when the new sea routes were discovered

via the Cape of Good Hope and the Magellan Strait to Southeast Asia, China and Australia, many new crops were added in the agricultural landscape of European countries. Corn (maize) was brought from Mexico and central American countries around 1500 AD which spread rapidly in the irrigated areas of Mediterranean region. Tobacco and tomato were also brought from Mexico during the same period. All the plants cultivated at present in Europe had reached the continent by the seventeenth century. Most of the grasses grown in Europe are indigenous to the Mediterranean region. Some new grasses were, however, diffused in Europe from the Nile basin, Africa, Americas, Asia, Australia and New Zealand.

Africa

The northern part of Africa was connected with the Southwest Asian Genecentre which helped in the diffusion of crops like wheat, barley, flax, legumes into Nile basin, coastal Mediterranean region, Sudan and Ethiopia. In the south of Sahara the Europeans penetrated only after the fifteenth century. Prior to the penetration by Europeans very few crops were sown in Africa excepting the Nile valley. By the middle of the nineteenth century maize was grown all over the continent of Africa. Sweet potato was introduced in West Africa from tropical Africa in the sixteenth century. Groundnut was brought from Brazil in the seventeenth century. Cocoa and rubber were brought from Brazil in the nineteenth century from Ethiopia. The history of cotton cultivation in Africa remained markedly complex. Cotton was being grown for lint in Egypt and Sudan (Nile basin) in the early Christian era. But whether these cottons were of Indian or African origin is not clear. American cotton was however introduced in West Africa most probably in the seventeenth century.

South and Southeast Asia

There had been very few changes in the agricultural practices and cropping pattern in India and Southeast Asia after the fifteenth century up to 1965 when the Green Revolution occurred. The American crops were introduced in Philippines and in other islands of Southeast Asia after the Great Age of Discovery.

In India, maize, chillies, tomatoes, sweet potatoes and pineapples were brought by the Portuguese in the early sixteenth century. Coffee

was first brought to India in 1600 by the Europeans and was planted in Mysore (Karnataka). Tobacco reached India in 1607 and it was more rapidly adopted. Tea is indigenous to Southeast Asian mainland but its cultivation got great encouragement during the British period after the establishment of the East India Company in India and the Dutch Company in Indo-China. Rubber was brought to India by the traders from Brazil after 1876. Cotton was domesticated in the Indus valley. Up to the seventeenth century cotton grown in India was all perennial shrubs. Good quality cotton (gossypium herbceum perssium) spread in India from Iran and the Nile valley. In Southeast Asia and China maize, sweet potatoes, manioca, groundnut, tobacco, oil-palm and rubber were introduced by the Dutch, Protuguese and British traders from the Central and South America.

The Americas

While trying to reach Southeast Asia by a western route, Columbus discovered North America in 1492. Prior to him the Red Indians were doing agriculture of the native plants. Wheat, barley and other crops grown in the Mediterranean region were diffused in America by Europeans between 1620 and 1700. The Indian migrants who were deployed in the sugarcane fields of West Indies brought with them the seeds of rice which, at present, is an important component of the cropping mosaic of tropical America. The Spanish and Portuguese also brought with them olive, fig, citrus fruits and vine Viticulture was introduced in California in 1798. Rubber is an indigenous plant of tropical America. The growth of motor car industry in 1890 gave rise to natural rubber production in Brazil. The Brazilian natural rubber is, however, finding it increasingly difficult to compete with the natural rubber of Malaysia and the synthetic rubber of the developed countries.

Cattle raising expanded rapidly in the New World. The need for fresh and large grazing areas drew cattle farming westward into Ohio and Kentucky, where corn for fattening purpose could be raised at low costs. Cattle were being driven overland to seaboard markets by 1805. The southern states of the United States had been the exporters of cotton and tobacco while the Middle West and Canadian plains are the wheat granaries. Corn grown in large quantities is generally fed to cattle, pigs and poultry.

Australia and New Zealand

Most of the crops grown in Australia and New Zealand have been diffused by the European colonizers during the eighteenth and nineteenth centuries Wheat, legumes, oilseeds, rice, cotton, sugarcane banana, and grapes were brought in Australia by the English traders The Pacific islands, Polynesia and Micronesia, however, remained isolated until the sixteenth century The Spanish rice spread in the Pacific islands in the sixteenth century, maize and manioca were widely developed in the eighteenth century in the region, while sugarcane, banana coffee, cocoa, rubber and citrus fruits were diffused in the Pacific islands in the nineteenth century

Development and Spread of Agricultural Technology

The history of technological advancement is a subject of great interest About the technology used in the cultivation of crops and domestication of animals there are numerous reasonable conjectures In fact, very little is known about the technology used by the palaeolithic and mesolithic societies In the early part of civilization fire was the man's first very important tool The use of fire gave hime more manipulative control over plants animals and wild beasts He made stone tools and developed mortar and quern He used stone axes, fire and digging sticks for the sowing of crops as the *Jhumas* of Mizoram Meghalaya and Nagaland still rely on them The development of copper bronze and iron metals in Anatolia (Turkey) between 8000 BC and 4000 BC helped in the making of better agricultural tools and implements Vegetation fire was the universal method of clearing bushes and undergrowth It was around 4000 BC that in Mesopotamia, Sumeria and Egypt primitive wooden plough, locally called as '*Ard*' was used for the ploughing of fields The original plough of Mesopotamia was merely a curved stock to which a flint hoe was tied to act as plough share The wooden plough was in use in the major agricultural communities excepting the Africans south of Sahara and Polynesia (Fig 2 17) The wooden plough having flint hoe was not very effective and only scratching of loose soil was possible with such a plough In the latter part of first millennium BC, iron shares became common in the Mediterranean region and China The plough was drawn by two yoked oxen Cross ploughing was

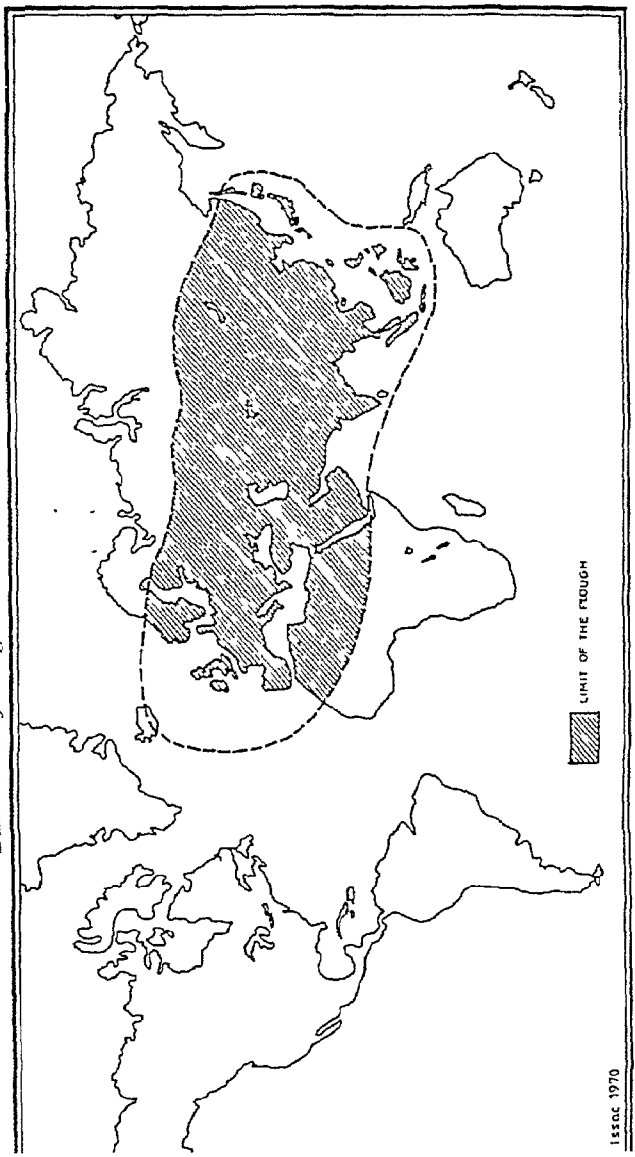


Figure 2.17
Distribution of Plough in Pre-Modern Times

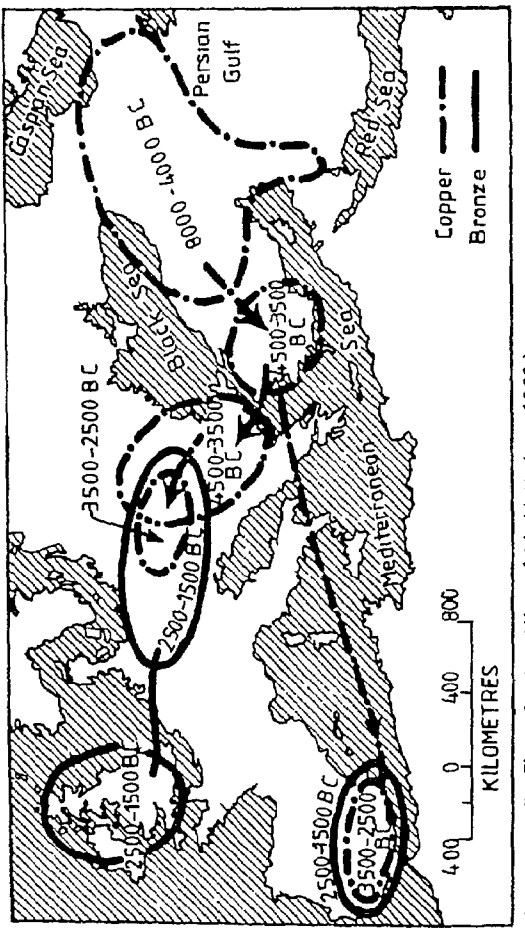
practised which helped in the conservation of soil (Fig. 2.17).

During the prehistoric period of agriculture, crops were sown by the simple broadcast method. This method continued in India, China and Europe till the nineteenth century. Even today, in may parts of the developing countries, the crops are grown with the broadcast method. Harrow was used for the first time probably by the Romans, the Indians and the Chinese. The farmers in these countries knew the use of animal manure. Terracing was done in Southwest Asia, South-east Asia and Peru. *Shaduf* irrigation was practised in Southwest Asia and Egypt.

In India, the Aryans came from a region near the Caspian Sea in about 1500 BC. They were Bronze Age people. In the battlefield, owing to their bronze swords and horse-drawn chariots, they established their superiority over the town dwellers of Mohenjodaro, Harappa and Rupar. In about 1000 BC, iron was discovered and iron technology was soon mastered (Fig. 2.18). With the help of iron plough shares, large new areas were brought under cultivation all over the then known world. In India, the iron technology led to the conquest of jungle infested areas of Uttar Pradesh and Bihar which became the centres of Aryan civilization. In agriculture, however, apart from the use of organic manure and plough, there was no remarkable progress In India, this may be largely due to the caste system which conceived and perpetuated division between the brain and the manual workers.

In Europe, a wheeled asymmetrical plough was in use by the late tenth century. Later a plough with two wheels was developed. The horse collar, which replaced the old harness band, that pressed upon animal's windpipe, severely restricting its tractive power, was one of the most important inventions in the history of agriculture. Apparently invented in China, the rigid padded horse collar allowed the animal to exert its full strength, enabling it to do heavier work, ploughing as well as haulage. Some farmers continued to plough with oxen. Some ploughing was done by two oxen as in former times four, eight or more were occasionally necessary in very difficult land. Wind power was applied to the grinding of grain by the earliest windmill. All these technological changes helped in the expansion of cultivated area and supply food for the growing population.

Figure 2.18
Diffusion of Early Metal Industry



(Based on The Times Concise Atlas of World History 1982.)

The great divide in the history of agricultural technology came in the middle of the nineteenth century The agricultural revolution in England occurred after the invention of the steam engine in 1779 which changed completely the face of the medieval pattern of agriculture in Europe Steam power was first applied to thrashing machines and irrigation pumps in the early part of the nineteenth century

In 1890, an important development took place in the wheat farms of Northwest United States This development was in the form of a tractor which was a large four wheeled machine driven by steam The first gasoline tractor was built in 1892 by John Froelich—an Iowa farmer and also a blacksmith The tractor with internal combustion engine was developed in 1910 The tractor equipped with diesel engine which enabled these machines to work under extremely adverse traction conditions came to be developed in 1931

Tractor began to replace horse, oxen, buffaloes and mules rapidly Less labour was needed to produce feed for the drought animals In 1991, the world production of tractors had reached about 2 25 crores and over half of these were produced in North America alone The result of these technological changes are spectacular In the United States, in 1800, 95 per cent people lived on farms and produced food to feed themselves and also the remaining 5 per cent employed in other vocations, today 25 per cent live on farms, and feed the remaining 75 per cent and produce enough to supply a large export to international market This radical change is largely the result of new agricultural technology, especially tractors, harvesters and chemical fertilizers The harvester replaced sickle in Europe in 1930 Chemical fertilizer appeared only in 1945 Pesticides were not widely available until the Second World War Now all these innovations including the new technology of High Yielding Variety chemical fertilizers, insecticides, pesticides, herbicides, fungicides, rodenticide, etc , are being used by the well off farmers of the developed and the developing countries

The spread, intensification in agriculture and the sophisticated agricultural technology have substantially transformed the cropping patterns of the world, providing food to the growing population and raw material to the agro-based industries These developments have,

however, adversely affected environmental quality. The impact of agricultural development on environment, society and economy will be discussed in the subsequent chapters.

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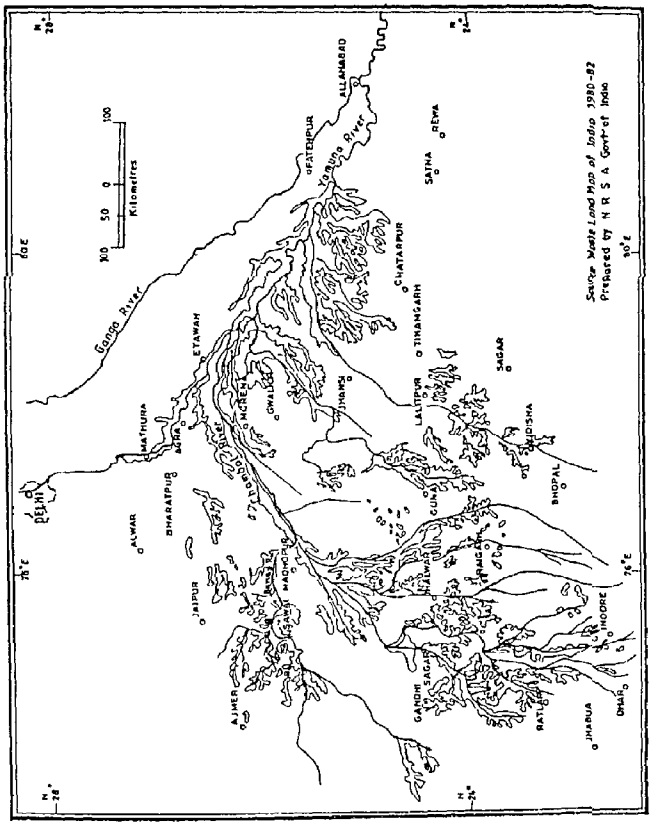
3 Physical Factors and Agriculture

Despite technological advancement and conquest over nature, the agricultural patterns are closely controlled by the physical factors. In fact, terrain, topography, slope, altitude, climate (temperature, rainfall, humidity, fog, frost, winds, sunshine), soils, surface drainage and underground water table are quite vital determinants of agricultural activities and cropping patterns

Terrain, Topography and Altitude

The agricultural patterns are strictly dependent on the conditions of terrain, topography and altitude. While the paddy cultivation requires levelled fields, the tea plantation performs well in the undulating topography in which water does not remain standing. Orchards of coconuts are found at low altitudes while apple orchards in tropical and subtropical areas are confined to elevations over 1500 metres above the sea level. Moreover, cultivation of crops is rarely done above 3500 metres above the sea level. The highly rarified air, low pressure, low temperature and shortage of oxygen at high altitudes are the serious impediments not only in the cultivation of crops but also in keeping dairy animals. At different altitudes and slopes the rainfall effectiveness also differs. The soils of high mountainous tracts are generally immature. Higher altitudes also result into variations in rainfall distribution. In general, the windward slope receives more rainfall than the leeward slope. For example, the rainfall recorded at Pune is less than half of the rainfall on the windward slope of the

Figure 3.1
Gullied or Ravinous Land:Chambal Valley



Western Ghats The amount of rainfall received in a region directly and indirectly affects the agriculture

Apart from altitude terrain, aspect of slope and the nature of surface also affect agricultural activity The gullied and ravinous land is least conducive for cropping The Chambal ravines in India have put a substantial fertile land out of agriculture (Fig 3 1) The reclamation of ravinous land is an expensive venture and agriculture in such reclaimed lands may be unremunerative unless provided with adequate irrigation facilities

Climate

Of all the physical factors, climate is quite significant that determines the agricultural land use and agricultural patterns of a region Climate consists of temperature rainfall, humidity, sunshine length of growing season, fog frost, snow, hailstorms, winds and air pressure All these elements of weather and climate, individually and collectively, determine the agricultural patterns of a region

Temperature

The crops to be grown, the agricultural operations and agricultural patterns are closely influenced by the prevailing temperature conditions of the region The agricultural scientists have proved that each crop has a specific zero below which it cannot grow There is also an optimal temperature in which the crop is at its greatest vigour For each of the functions of crop life, weather germination, foliation, blossoming or fructification a specific zero and optimum can be observed in the temperature

The impact of temperature on agricultural patterns may be seen from the fact that the northern limit of the regions in which the date-palm bears ripe fruit coincides almost exactly with the mean annual isotherm of 19° C The essential factor in the limit of grape orchards seems to be the temperature in summer, for the grape ripens only in those countries in which the mean temperature from April to October exceeds 15° C Similarly, it has been calculated that maize ripens at the period of the year when the sum of the daily maximum temperatures has reached 2500° C

In general, crops like barley, rye, oats and winter wheat perform well when the mean daily temperature ranges between 15° C and 25°

C. Contrarily, tropical crops like cacao, coffee, spices, squash, dates, rubber, and tobacco require high temperature throughout the year, while crops like peas, gram, lentil, wheat, potato, mustard, rapeseed, linseed, lucern and barseem require relatively warm temperatures during the growing and ripening periods and low temperatures (around 20° C) during the growth and development stage.

The upper temperature limit for plants growth is 60° C under high temperature conditions, i.e., over 40° C, crops dry up if the moisture supply is inadequate Moreover, under high temperatures, the growth of plants is retarded. The adverse effect of very high temperature on crop, however, may be reduced by increasing the supply of moisture to the crop through irrigation and/or moisture conservation tillage practices. It is because of this reason that the seedlings of tea are shaded by silver oak to protect them from the direct rays of the sun. Similarly, many vegetables in oases, deserts and tropical areas are grown under shades to protect them against the heat and high temperature. In the areas of low temperatures (temperate and mountainous areas) sensitive vegetables and flowers are grown in green houses under controlled temperature conditions.

In contrast to high temperatures, the crops also have a minimum temperature limit. The chilling and freezing temperatures have great adverse effect on the germination, growth, ripening and yields of crops. Low and freezing temperatures retard growth of plants and kill certain plants which are adapted only to warm temperatures. Crops like rice, sugarcane, jute, cotton, chillies and tomatoes are killed by the near freezing temperatures persisting for two or three days. The minimum temperature for rye is 2° C, for wheat 5° C, for maize 9° C and for rice about 20° C.

In addition to mean minimum and mean maximum, each crop has a minimum requirement of accumulated temperature. For example, wheat requires 2000 day degree celsius (temperature required throughout the crop season from sowing to ripening), while successful rice crop requires 3000-4000 day degree celsius during the entire growth period. It has been observed that application of cold water to a crop retards its growth by reducing temperatures of the soil and the immediate surface.

The influence of low temperatures varies greatly with different crops. Some crops, e.g, potato and sugarbeet, store carbohydrates

more rapidly in the cool nights, while cotton, maize and tobacco require warm night for the optimal growth and better yields Apples peaches mangoes, litchis laocawts etc complete fructification during the warm season and their trees can survive the low temperatures in the subsequent winter season

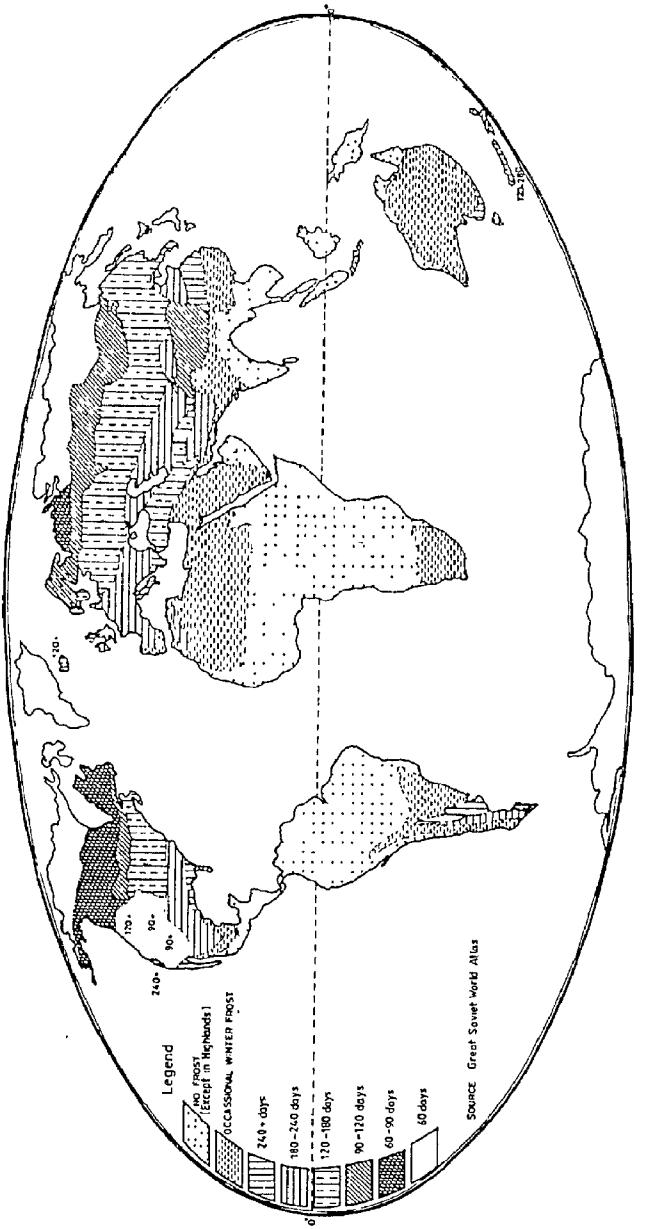
Apart from temperatures the duration of sunlight and luminosity of the atmosphere are also important factors which influence the agricultural patterns The distribution of light varies with latitude The maximum duration of sunshine in any one day increases towards the poles, being 14 hours 34 minutes in latitude 40°, 15 hours 45 minutes in latitude 50° and 24 hours in latitude 68° in summer In cold countries the action of light hastens growth For example, spring barley ripens in 107 days in southern Sweden but in only 89 days in Lapland in spite of the far lower temperature this being compensated for by a far longer period of insolation Thus, in polar regions, the intensity of light partly compensates for the shortness of the warm season and explains the rapidity of the vegetative process in plants In Russia Canadian North Alaska and Greenland farmers have skilfully taken advantage of this compensation

Sunshine

Light plays an important part in photosynthesis activity in plants The time required by a crop to achieve maturity is a function of the length of the day (photo period) and, therefore, preference for a variety is judged by its maximum utilization of light energy In general, a crop planted in the winter season requires more calendar days to mature than the same crop planted later In cloudy areas, cloud cover often reduces the amount of light available This has great significance in regions where ripening of crops and their harvesting in dry condition are often in doubt Cloud cover and excessive rainfall also prevent double cropping

Frost

Frost is also an important factor which restricts the cultivation of crops at higher latitudes and altitudes The sowing dates, germination, emergence of seeds, dates of budding, flowering, ripening and dates of harvest are all affected by frost free period in a given region The phenomenon of frost, however, does not occur in the lowlands of the equatorial and tropical regions Frost free period is progressively



Average Length of Frost Free Period

shorter with increasing latitudes(Fig.3.2).

In the areas of frost occurrence, frost kills the standing crops. Many a time, the damage may be disastrous over larger areas The occurrence of frost during the earlier stages of plant growth before plants have made the necessary physiological adjustments may be hazardous. In the tropical latitudes the citrus orchards are highly vulnerable to frost. Germinating seeds are not often affected by surface frost, but young seedlings may be damaged or killed unless they are frost hardy varieties. Crops like tomatoes, potatoes, melon, cucumber and musk-melon are highly frost sensitive right up to their maturity The flowering stage of all cereals and orchard crops is also critically vulnerable to frost The quality and quantity of all crops including the orchard crops are adversely affected under frost conditions. Fruits affected by frost are less tasty and have little market value. Frost resistant crops are grown in areas susceptible to frequent frost.

In the frost affected areas a logical adjustment to frost is to select frost hardy plants. Direct steps to prevent frost occurrence may also be taken. The air may be heated or a protective blanket of smoke may be provided or the two methods may be combined to raise the surface and soil temperature during the night times. Frost preventive methods work only if the atmosphere is clam as the blowing of winds causes the different temperatures to mix up. Cheap oil or any fuel may be used to spread smog on the trees in the orchards. Smog reduces the loss of heat by radiation in much the same way that a cloud cover does. More efficient heaters which give off less smoke are now more common in the orchards of Florida, California, Rhone valley, Japan and many other developed agrarian regions of the world. The direct heating of lower atmosphere with the help of these heaters often avert the danger of frost. The surface air can be mixed up by means of huge fans, operated usually by electric motors. Aeroplanes and helicopters have also been used in the developed countries to fan the air above crops, but this is an expensive procedure. In the developing countries of Asia, tender plants and nurseries of crops like cucumber, melon and young winter vegetable plants are usually covered with straw for frost protection during the early stages of growth. The irrigation of crops also averts the danger of frosting to an appreciable extent.

Moisture

All crops need water. They take water and moisture from the soil. This moisture may be available from rains or from surface or underground irrigation systems Within wide temperature limits, moisture is more important than any other environmental factor in crop production. There are optimum moisture conditions for crop development just as there are optimum temperature conditions. Plants obtain their water supplies primarily through their root system. The maintenance of soil moisture is, therefore, the most compelling problem of agriculture. The excessive amount of water in the soil alters various chemical and biological processes, limiting the amount of oxygen and increasing the formation of compounds that are toxic to plant roots. The excess of water in the soil, therefore, leads to stunted growth of plants. The problem of inadequate oxygen in the soil can be solved by drainage practices in an ill-drained tract.

Rain is the cheapest source of water provided it is timely and adequate in quantity. But rainfall in the greater parts of the world is uncertain and highly unevenly distributed. Failure of rains or excessive rainfall in a short period have brought repeated crop failures and famines in many parts of the world. Indian farmers like others have often suffered on account of the failure of rains or fury of floods.

Heavy rainfall may directly damage plants or interfere with flowering and pollination. Cereal crops are often lodged by rain and this makes harvest difficult and promotes spoilage and disease. Heavy rain during the maturity stage of wheat, rice, gram, millet and oilseeds causes loss of both seed and fodder. The occurrence of hail at the maturing stage of crops causes direct damage to plants, locally and for *rabi* crops (winter crops), it may be a disaster. The intensity of damage depends on the stage of growth of crop and the intensity of the hailstorm The areas in India in which hail normally causes the most damage are the Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Madhya Pradesh and the entire Himalayan belt. Hails generally occur during the *rabi* season when the major grain crops of wheat, gram, barley, etc., are in the fields.

Drought

Drought has devastating consequences on the crops and land use of a

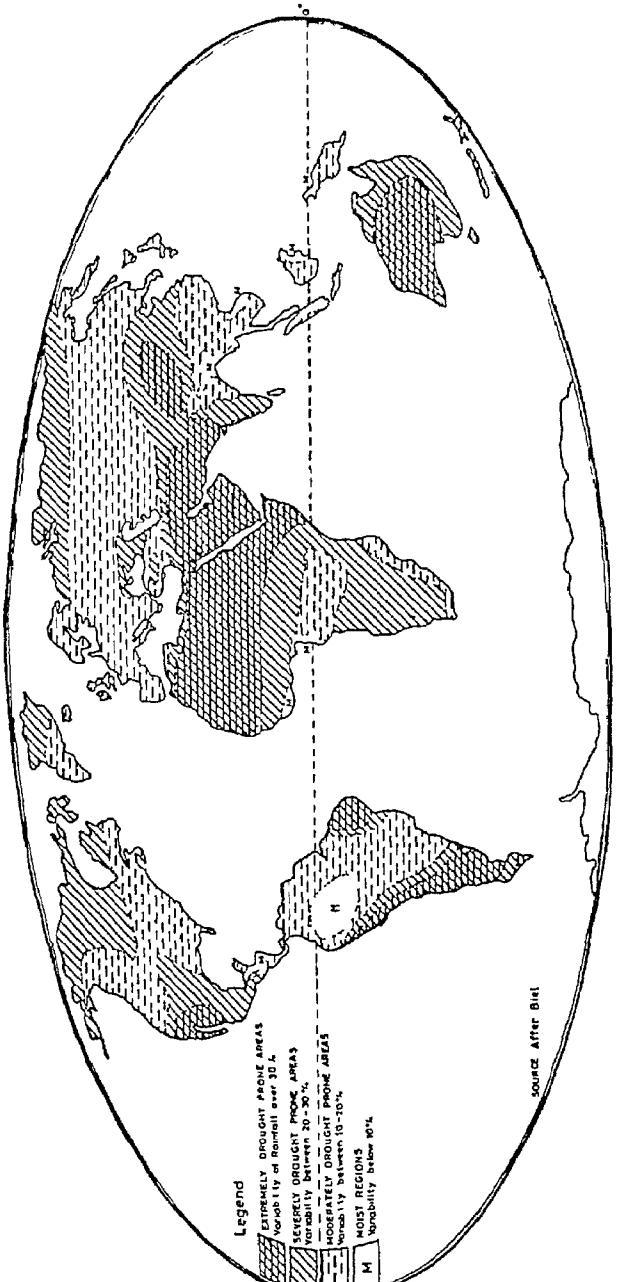
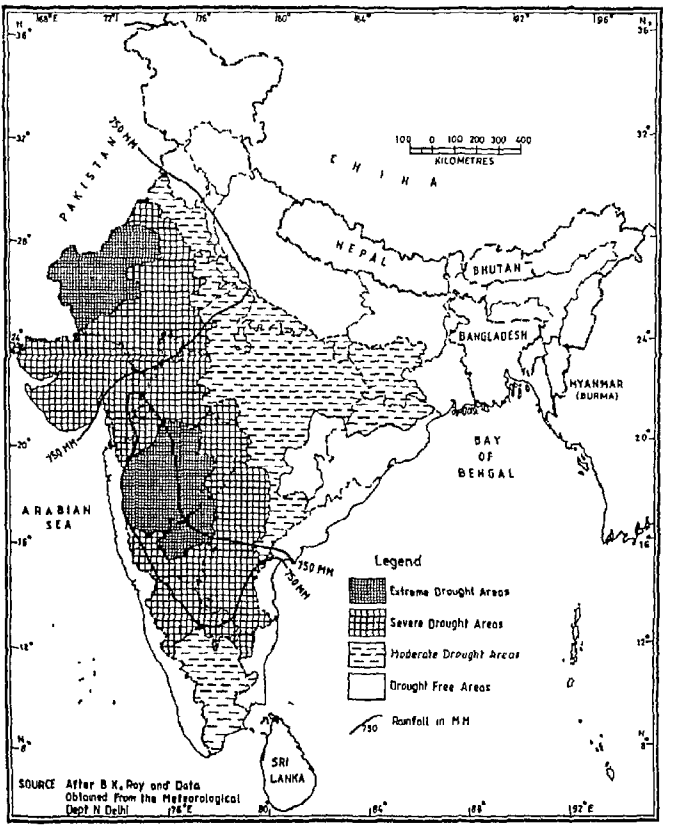


Figure 3.3
Drought Severity Map

Figure 3.4
India:Drought Prone Areas



region. Soil drought has been described as a condition in which the amount of water needed for transpiration and direct evaporation exceeds the amount available in the soil. Drought damages the crops when plants are inadequately supplied with moisture from the soil. Land use practices which tend to increase run off decrease vital soil moisture storage accordingly.

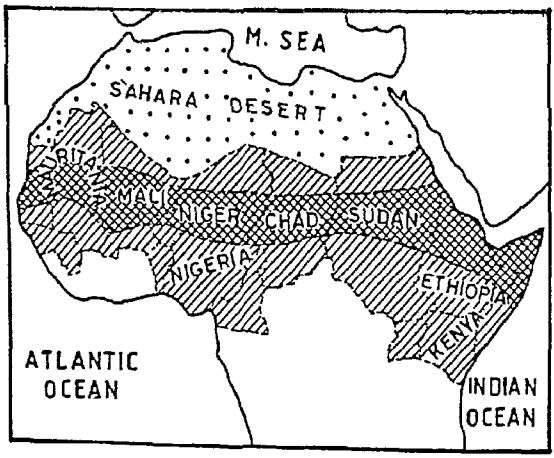
The drought prone areas and the severity of drought in the world have been plotted in Figure 3.3. It may be seen from Fig. 3.3 that the greater parts of Northern Africa, Southwest Asia, Central Asia, and central Australia are extremely drought prone. There are substantial tracts in western USA, Chile and southern Argentina in which the variability of rainfall is between 20 and 30 per cent. These areas are also prone to severe drought.

The drought prone areas of India lie in the states of Rajasthan, Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh and Karnataka (Fig.3.4). Agriculture in the greater parts of India is still considered a gamble on monsoon.

The worst drought affected area in the world is Sahel region which stretches across the African continent in Mauritania, Mali, Niger, Chad, Sudan and Ethiopia (Fig.3.5). The vast arid environment

Figure 3.5

The Sahel Region (Africa)



of Sahel experiences considerable rainfall and climatic fluctuations

The incidence of drought can be determined from the annual, seasonal and diurnal distribution of rainfall, its dependability, intensity and the form of precipitation Moreover, different plants have different moisture requirements In the greater parts of India a delay in the onset of summer monsoon may be disastrous as the *kharif* sowings may be delayed, especially in the rainfed areas In the past, some of the worst famines in the subcontinent of India have resulted from failure of the summer monsoon In the semiarid climates, like that of Rajasthan, slight departure from normal in the quantity of rainfall may be a critical factor in crop failure

Cultivation practices that improve the soil structure and inhibit run off are effective drought prevention measures, although they have limitations For the effective use of available moisture for the crops, weed control has great significance In the semiarid areas of *high rainfall variability like the districts of eastern Rajasthan, dry* farming method is a useful device which helps in the conservation of soil moisture In the arid regions agriculture is possible only if irrigation water is available to the crops at the critical stages of plant growth and flowering, while in the semiarid regions irrigation enables the farmers to obtain higher yields and a greater variety of crops

In the humid regions the main value of irrigation is supplementary in times of drought The development of sources of irrigation is, however, not possible everywhere owing to certain physical and economic constraints The main limitations on irrigation are the availability of the surface and underground water, the cost of getting it to the fields and the nature of crops to be cultivated Nevertheless, irrigation is man's best answer to drought Where irrigation water is made available, temperature becomes the dominant climatic factor controlling crop distribution and yields In Punjab, Haryana and western Uttar Pradesh, irrigation has assured the cultivation of valuable crops like sugarcane, wheat, rice, barseem and potatoes It can, however, be said that unless irrigation facilities are provided to cope with the vagaries of rainfall, the land will only be arable at the risk of disastrous famine Although it can produce a bumper crop one year, it may be a pitiful sight of disaster in the next

Snow

Snowfall is also an important climatic constraint in the agricultural operations. It results into hardship to livestock and damage to the crops. Hill sheep farming in Scottish highlands and Welsh mountains is adapted to snow conditions and the sheep are moved to safer areas when snowfall is severe. Sheep can live for two weeks or so in snow drifts but rescue operations are arduous and losses are heavy. In plain areas of higher latitudes fodder crops are damaged, leading to fodder shortages.

The occurrence of snow reduces the ground temperature which hinders the germination and growth of crops. Land under snow cannot be prepared for sowing because of soil freezing. Snow, however, protects the standing crops from frost and drying winds. Certain parasitic fungi find suitable conditions for breeding under snow cover and attack plant seeds. Severe snow may cause heavy losses of crop, livestock and property and always lead to shortages of fodder. It may also result into the death of large number of new born lambs. Melting of snow may cause hazardous floods in the summer season, affecting the crops, livestock, land and property adversely.

Winds

In addition to temperature and moisture conditions in a region, winds' direction and their intensity also have an influence on the cropping pattern and agricultural productivity of the region. The cold and dry severe winds in the northern plains of China, for example, restrict the growth of certain crops which otherwise could have been grown there. In the arid and semiarid areas, hot winds do great damage to agriculture and, therefore, in the hot deserts, growing of crops is confined only to the tiny patches of oases.

Winds have both the direct and indirect effects on crops. Direct winds result into the breaking of plant structures, dislodging of cereals, fodder and cash crops and shattering of the seed-heads. Fruit and nut crops may be stripped from the trees in high winds Small plants are sometimes completely covered by wind-blown dust or sand. The indirect winds transport moisture and heat in the air. The movement of winds increases evaporation.

In many countries, very strong and 'killing winds' are associated

with particular directions of origin. The *mistral*, a cold northerly wind blowing down in the Rhone valley and southern France, brings heavy losses to growers of olive, figs, citrus and other fruits. In contrast, the *sirocco* from the Sahara is a hot drying wind that blows on the northern African coast. Hot dry winds called *loo* in the northern plains of India in the months of May and June damage the standing crops of fodder and sugarcane in the unirrigated parts. The strong dry winds lead to soil erosion in the fallow lands of the semiarid regions, especially during the summer season.

The adverse effect of dry winds in the form of evaporization can be averted by irrigation. Mechanical damage to crops can be lessened by making use of natural or artificial shelter. Wind breaks, composed of trees, shrubs, hedges or fences are widely used to protect both plants and animals from the hot and cold winds. The most suitable permanent wind breaks are the rows of trees planted perpendicular to the prevailing winds. Trees, however, reduce the area of cultivated land, compete for soil moisture and may produce harmful shades. The suitable species of trees, therefore, need to be selected for planting the trees for wind breaks.

Cultivators, especially those of developed countries, equipped with modern technology, may grow any crop anywhere if labour and expenses are not in question. Cereal and non-cereal crops like rice, sugarcane, tea and rubber that flourish in warm and moist climate can be grown in the areas of low temperatures of high latitudes. But, for economic reasons, crops are generally grown where they may fetch the maximum agricultural returns and profits to the growers. Crops being highly vulnerable under adverse climatic conditions are mostly grown in the areas of conducive temperature and moisture conditions.

Soils

In any agricultural operation soil is of the utmost importance as it is the cradle for all crops and plants. The top soil having an average depth of about 15 to 20 cm on the face of the land, is the natural body of soil on which plants grow and the farming activities flourish. The standard of living of the people depending on agriculture is often determined by the fertility and productivity of soils.

The word soil is derived from the Latin word solum. In general, soil refers to the loose surface of the earth as distinguished from solid rock. It is the material that nourishes and supports growing plants. According to the soil scientists, soil means that part of the earth's crust which has been changed as a result of soil forming processes. It is a natural aggregate of mineral grains, with or without organic constituents, formed by the chemical and mechanical weathering of rock.

DoKuchayev defines soil as a body subjected to a natural and historical development, which came into being on the surface of the earth as a result of a complex combination of the interaction of rocks, the organic macro and micro organism of vegetable and animal worlds, the climate, the local relief and the production activities of man. It consists of three phases: solid mineral matter, water and air or gases.

Soil formation proceeds in steps and stages, inseparably interrelated It develops through a prolonged interaction between soil forming rocks, the organic world and the environment. The geological, biological, hydrological, lithological, social and economic factors influence the course of soil formation. The development of soil is largely influenced by the parent material, climate, living organisms, topography, land utilization and time.

Parent Material

Soils are formed by the weathered igneous, sedimentary and metamorphic rocks. Solid rocks disintegrate slowly under the influence of weathering, which acts on them through sunshine, rain, frost and wind. Heating and cooling, freezing and thawing, wetting and drying—all tend to weaken the rock structure. These forces finally break up a rock into small pieces. The loose and weathered rock materials may then become soils parent material. When this weathered complex material begins to support life (plants, insects, bacteria, worms), the chemical and physical changes are accelerated. Thus, the major characteristics of the soil depend on the parent material.

Climate

Climate is the most effective factor in soil formation and its fertility. Temperature and rainfall govern rates of weathering of rocks and the

decomposition of minerals Climate functions directly in the accumulation of soil parent materials and the differentiation of horizons The indirect effects of climate are through its controls over the kind of plants and animals that can thrive in a region

In general, the climate may be grouped into three broad categories first, there is the frigid climate in which the precipitation is generally in the form of snow, secondly, there is the humid climate in which the precipitation exceeds evaporation from surface, and thirdly, there is the arid climate in which the evaporation from the surface of the soil is substantially higher than the amount of atmospheric precipitation The soils of different climatic regions differ appreciably in their characteristics and properties The great soil belts are associated with climatic types Moreover, the amount of humus in soil also depends on the climatic conditions There is more humus in soils of a moderately warm climate than in soils of a cold or arid-dry climates

The soils that correspond to the great climatic belts are called zonal soils, those that depart from the surrounding zonal soils because they are derived from parent materials, attributing special characteristics to them (such as limestone) are called intra-zonal soils, while those in which time has not been sufficient for recently deposited materials to weather in the form appropriate to the climatic zone are called azonal soils This broad classification is not of much agricultural importance as it does not take into consideration the meso and micro properties of the soils which play a vital role in the cultivation of crops

Soils in which the layered structure is well developed and distinct are called zonal or normal, while those without this well developed vertical profile are called azonal

From the agricultural utilitarian point of view the zonal soils are to be classified into pedalfers and pedocals The excessive leaching of iron, together with calcium carbonate and other substances, from the upper horizons of the soil characterize the pedalfers, while soils in which lime is accumulated in the upper parts of the soils are called pedocals In the peadocal soils the acidity decreases as precipitation fails to meet the needs of potential evapotranspiration In the semiarid and dry climates alkaline compounds accumulate near the

surface and since the amount of organic matter diminishes progressively as conditions become drier, the soils are lighter in colour and have shallower top layer.

Living Organisms

Living organisms of the plants, animals, insects, bacteria, and fungi are important because they improve soil fertility by breaking down plant and animal tissues. During this process, the nutrients released and the minerals fixed are incorporated into the soil. On one hand, the plants and animals differentiate the soil horizons and on the other they accumulate some quantity of soil parent materials. The quantity of organic matter and nitrogen in the soil, gain or loss in plant nutrients, and changes in its structure and porosity are caused by living organisms. The plants and animals may also mix horizons and thus retard their differentiation.

The plants largely determine the kinds and amounts of organic matter that go into a soil under natural conditions. Some plants take their nitrogen from the air and add it to the soil as they die. The deep-root plants check soil erosion. Bacteria and fungi live mainly on the plant and animal residues. They breakdown complex compounds into simpler forms, as in the decay of organic matter. Some micro organisms fix nitrogen from the atmosphere and thus add it to the soil when they die.

Organic matter added into the soils by plants and animals improves the soil chemically by serving as a store house or supply of plant nutrients. Various organic and inorganic acids are produced in soils when organic matter decays, and they have a very pronounced dissolving effect on soil minerals. Moreover, the organic matter and humus content in the soils increase the water retaining capacity of soil, decrease water run off losses, improve aeration and produce a better soil structure. Although most soil micro organisms are beneficial, yet there are some which are harmful too. These are called pathogens and cause root rots in higher plants.

Topography

Soils and their properties are also influenced directly and closely by topography, relief and altitudes. Topography affects run off and drainage. Other things being the same, the run off is large on steep

slopes. The drainage is rapid in the mountainous tracts of steep slopes and slow in the level plains and valleys. The amount of water that moves through the soil depends partly on topography. As a rule, more water run off, lesser its absorption in the soil on steep slopes. The run off also washes away more of the weathered rocks on steeper slopes. The depth of soil and soil profile on steeper slopes is shallower than on gentle slope. If water stands on the surface peat deposits may be formed. Topography thus influences the moisture regime in the soil and the erosion rate that determine the properties and fertility of the soil.

Soils are also influenced by altitudes. The effect of altitudes can be observed significantly in the mountainous regions of higher altitudes. The soils of mountains and valleys vary greatly over short distances. Their complex spatial patterns make it impossible to represent them on a small scale map. Many soils in the hilly tracts are shallow and immature because of steep sites and rapid erosional processes. Others are formed under unique local conditions of climate induced by relief and drainage. The soils, having well developed profiles, are found on gentle slopes or in broad valleys. The altitudinal zonation of mountain soils coincides broadly with high land vegetation. Alpine soils, for example, are roughly analogous to tundra soils.

A typical soil zonal profile proceeds in the hilly areas. In the upper parts of the slops, there is a formation of washed-off soils and towards the bases of the slopes, there is the formation of washed-in soils. Only on gentle slopes with a gradient of less than 5° there is a formation of soils with a profile near to normal, owing to the fact that erosion is only slight and has no influence upon the formation of a typical soil profile. The erosion is low on gentle (5°-10°), moderate (10°-15°) and pronounced (15°-20°) slopes. On steep slopes (20°-45°), the erosion is so marked and the surface so denuded that the soil cover subsists only in the shape of isolated patches preserved from wash-out. On precipitous slopes (45°) usually rocks appear and there is no soil cover. The inclination of slopes may, other things being equal, influence the mechanical composition of parent rocks and soils. Thus, the topography, relief and altitude have inalienable role in the formation of soils.

Land Utilization

Soils are largely influenced by the tillage practices and production activity of man Man utilized soils with the purpose of obtaining maximum profits and many a time without caring much about its future fertility Thus, the soil becomes exhausted The soil of enormous areas has lost its structure, and at places, has been eroded by water or wind Indiscriminate irrigation of land led, in many tracts, to mass salinization and swamping of soils The Indira Gandhi Canal catchment provides an example of waterlogging and salinization The burning down of forests in the shifting cultivation areas of the hilly tracts of the northeastern region of India has resulted in the depletion of soils At present, the importance of soils has been increasingly realized and, therefore, keeping the soils in sound health is the major concern of the farmers and soil scientists all over the world In many areas the character of soils has been changed by man to suit the land use and cropping patterns

Time

Soil formation is a slow and gradual process Unlike land forms, soils possess a history In fact, a tremendous interval is needed for the development of soil from freshly exposed rocks For example, the development of soils in the limestone rocks is a time consuming process because it dissolves very slowly in water Millions of years may pass before the parent materials assimilate to form good soil Soil age, therefore, has a great influence on soil properties The age of a soil is usually measured from the time the rock was first exposed to the surface or from the time the alluvial material was deposited

Textural Classification of Soils

Soils are also classified on the basis of texture Texture means the size of individual mineral particles Thus, the term 'soil texture' refers to the size of soil particles and their arrangement An international classification system defines particles with diametre less than 0 002 millimetre as clay, those with diametre between 0 002 and 0 02 millimetre as silt, and particles between 0 02 and 2 millimetres in diametre as sand The term 'loam' is used to describe mixture of the different size-classes of soil particles A standard classification scheme based on the proportion of clay, silt and sand in the soil is

given in Table 3.1 and illustrated in Figure 3.6.

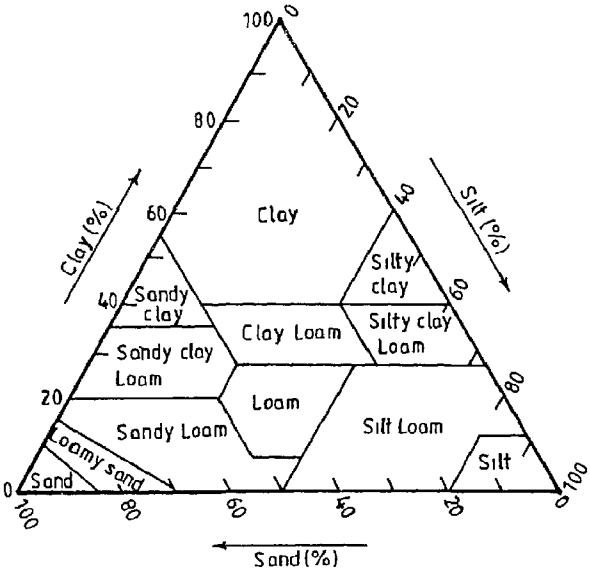
Table 3.1

International Scale for the Classification of Soil Texture

Name of Soil Particle	*Diametre (mm)*
Fine gravel	2.0-1.0
Coarse sand	1.0-0.5
Medium sand	0.5-0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05
Silt	0.05-0.002
Clay	Less than 0.002

Figure 3.6

Soil Classification by Texture



(From Janick et al Data from U S Department of Agriculture)

Soil texture influences the rate at which water percolates through soil and the amount of water a soil can contain. Coarse soils are characterized by rapid infiltration, and hence low surface run-off, but they cannot retain much water. The fine textured clays are penetrated by water only slowly but have a high storage capacity. The pore space in soil, which is filled in varying proportions by water and air, is typically about 50 per cent in many kinds of soils; what is more important than the total volume of pore space is the characteristic size of individual pore spaces. Few large pores make a much less satisfactory soil than many small ones. Soil organism and organic matter are crucial in maintaining the better situation by preventing excessive coagulation of soil particles into large clods.

Soil Profile

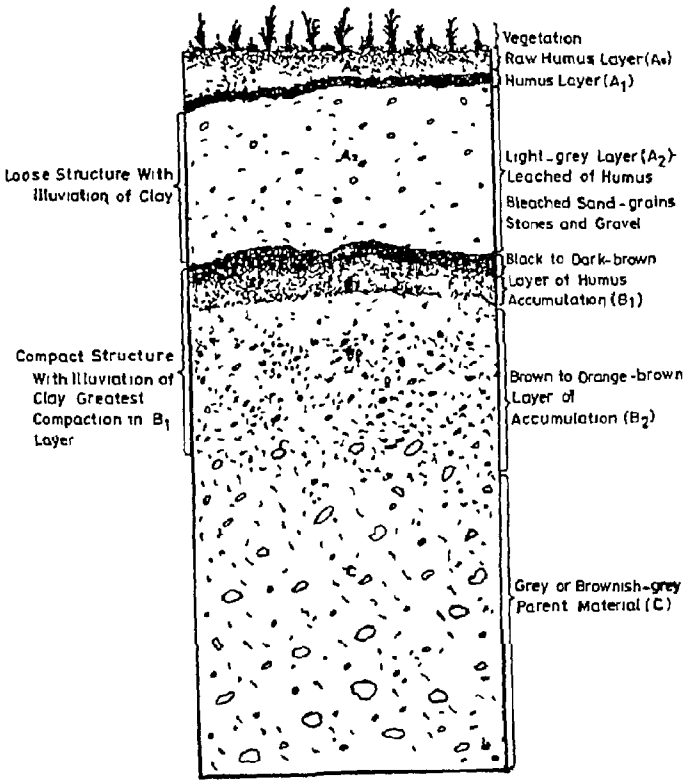
A soil profile is a succession of layers in a vertical section down into loose weathered rock (Fig.3.7). A soil profile consists of two or more layers, lying one below the other and almost parallel to the land surface. The layers are known as horizon. Most soil profiles include three master horizons, identified by the letters A, B and C. When a soil is used without proper care, the A and B horizons get eroded away. The soil profile is influenced by all the morphological characters, climate and land use practices. The uppermost soil horizon is usually coloured to a certain depth by humus, sometimes down to one metre and more, but in most cases not exceeding a few centimetres. The thickness of soil horizons varies within a short distance in a horizontal direction, even on a relatively plane surface. Moreover, some horizons grow thicker, whereas others grow thinner, in full accordance with the manifestation of the soil forming factors. The changes in morphological characteristics have been shown in Figure 3.7.

Classification of Soils

As discussed in the preceding paras the rocks and their mineral compositions differ from region to region. Same is the case with climatic conditions on which depends the natural vegetation, humus and micro organism. Owing to these variations the soils differ from place to place. Several major types of soil forming regimes have been identified as podzolization, laterization, calcification, gleization and salini-

Figure 3 7

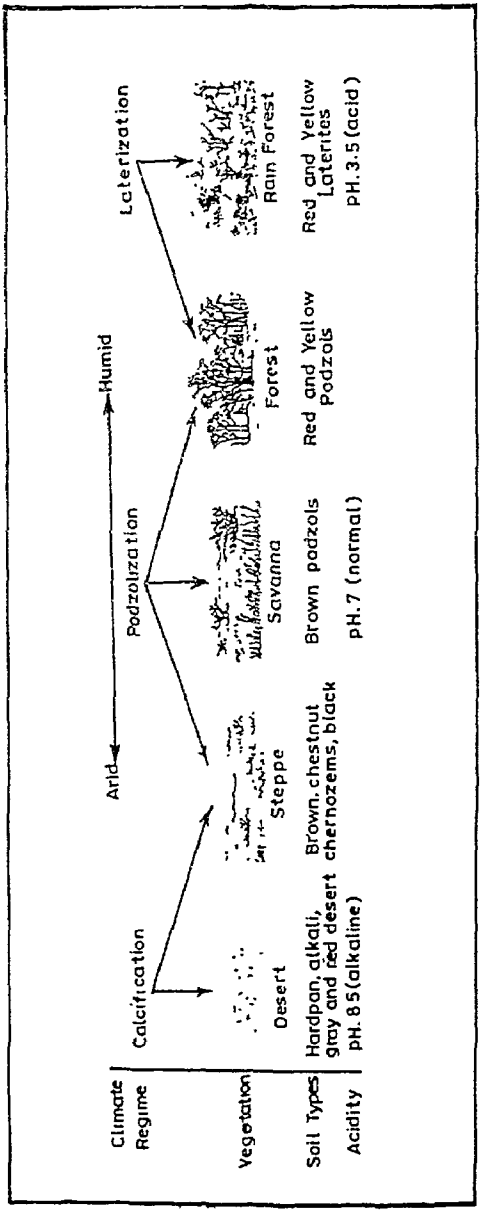
Texture and Structure of Soil—A Typical Podsol Profile of Soil



After G W Robinson

Figure 3.8

Relation of Soil Forming Regimes, Vegetation and Soil Types



(Adopted from Janick et al, 1974)

zation.

Podzolization is the set of processes associated in its extreme form with cool climates, abundant precipitation, and acid upper soil layers strongly leached of mineral nutrients and the oxides of iron and aluminum. The nutrients, oxides and humus accumulate in the deeper layers. Fungi are the main soil forming organisms. Those soils are characteristic of northern forests, although they exist in some circumstances well into temperate and subtropical regions.

Laterization is a set of processes associated with the humid tropics and subtropics. High mean temperatures in these regions permit sustained and rapid bacterial action, which minimizes the accumulation of plant litter and humus. In the absence of the organic acids associated with humus, the soil is neutral, rendering the oxides of iron and aluminium relatively insoluble; those oxides accumulate in the upper soil horizons as hard clays and rock-like material called laterite (from the Latin for brick), a mixture of $Fe_2O_3.nH_2O$ and $Al_2O_3.H_2O$.

Calcification occurs in climates where evapotranspiration exceeds precipitation. There is little leaching of the metallic cations, and microbial activity is slow, so the soils tend to be alkaline and rich in humus. Calcium carbonate in solution is carried upward from the water table by capillary action in the season of little surface moisture and is left in the upper soil horizons in solid form when the water evaporates.

Gleization is the set of processes characteristic of poorly drained environments in cool or cold climates. The low temperatures permit heavy accumulation of organic matter, and the excessive wetting produces a stickly clay underneath.

Salinization is the regime characterized by accumulation of highly soluble salts in the soil. This situation arises naturally from poor drainage in regions of low precipitation and high temperatures (deserts), and it can be brought about by faulty agricultural practices—irrigating too parsimoniously in dry climates, or using salt-laden irrigation water. Soils in the salinization regime are weakly to strongly alkaline.

The geographical boundaries separating the spheres of influence of the different soil forming regimes are often not distinct. An enormous variety of soils results from variations within regimes and from

overlaps between regimes, and a quite complicated classification scheme and taxonomy for soils (the United States comprehensive system of soil classification) has been devised to help soil scientists cope with this diversity. Figure 3.8 is a schematic illustration of how a few of the principal soil types emerge from the soil forming regimes. Characteristics of a somewhat broader selection of soil types encountered in the literature of soil science and biogeography are summarized in Table 3 2.

Table 3.2

Characteristics of Common Soils

	Pedalfers (soils of humid regions)
Tundra soil	Dark-brown, peaty layer over gray horizons mottled with rust, substrate permanently frozen *Climate* frigid, humid *Vegetation* lichens, mosses, herbs, shrubs *Process* gleization (development of organic-rich, sticky, compact, clayey layer due to excessive wetting)
Alpine meadow	*Dark-brown, organic-rich layer grading down at 30 to 60 cm to gray* and rusty soil, streaked and mottled *Climate* cool temperate to frigid *Vegetation* grasses, sedges, herbs *Process* gleization, some calcification (deposition of calcium carbonate)
Bog and half-bog	Brown, dark-brown, or black peaty material over soils of mineral matter mottled gray and rust *Climate* cool to tropical, generally humid *Vegetation* swamp, forest, sedges, or grasses *Process* gleization
Podzol, brown podzol, gray-brown podzol	Leaf litter over a humus-rich layer over a whitish-gray to grayish-brown leached layer, B horizon clayey and brown Acid *Climate* cool, temperate, humid *Vegetation* northern forests, coniferous and/or deciduous *Process* podzolization (bases-Al and Fe—leached more than silica from A horizon and accumulated in B horizon)
Red and yellow podzol	Thin, dark organic layer at surface over yellow-gray or gray-brown leached layer 15 to 90 cm thick, over clayey B horizon over parent material mottled red, yellow, and gray *Climate* warm temperate to tropical humid *Vegetation* coniferous forest or mixed deciduous and coniferous *Process* podzolization superimposed on lateritization (silica leached more than the bases)
Prairie and reddish prairie	Brown in the north, reddish-brown toward the south Grades down to lighter-coloured parent material with no horizon of carbonate accumulation *Climate* cool temperate to warm temperate, humid *Vegetation* tall grass *Process* weak podzolization

Contd

Contd

	Pedocals (soils of arid regions)
Chernozem	Black to gray-brown crumbly soil to a depth of 90 to 120 cm, grading through lighter colour to a layer of carbonate accumulation *Climate* subhumid, temperate to cool *Vegetation* tall grass *Process* calcification (accumulation of carbonates in lower horizons)
Chestnut, brown, reddish chestnut, and reddish brown	Brown to black surface layer in north, reddish in south, lighter colour at depth and grading down to layer of carbonate accumulation Chestnut thinner than chenozem, and brown thinner than chestnut *Climate* semiarid, cool to hot *Vegetation* mostly short grasses in north, grasses and shrub in south *Process* calcification
Desert, sierozem, red desert	Light gray or brown in north, reddish in south, low in organic matter, carbonate layer generally within 30 cm of the surface *Climate* arid, cool to hot *Vegetation* mostly desert shrubs *Process* calcification
	Other soils
Rendzina	Dark-gray or black, organic-rich, surface layers over soft light gray or white calcareous material derived from chalk, soft limestone, or marl *Climate* variable *Vegetation* mostly grassland *Process* the lime in these soils is derived from the parent materials
Laterite	Thin organic layer over reddish, strongly leached soil, generally clayey and enriched in hydrous alumina or iron oxide or both, low in silica, generally many feet thick Climate tropical wet Vegetation mostly forest Process lateritization (see red and yellow Podzol)
Saline and alkaline	Soils in which salts including alkali have accumulated, generally in poorly drained areas *Climate* variable, but commonly arid or semiarid *Vegetation* salt-tolerant species or lacking *Process* salinization or alkalization (salts deposited in soil as a result of evaporation)

Source Hunt, *Physiography of the United States*

pH Value of Soil

The presence of water in the soil is also a significant determinant of soil aeration and its fertility. The various forms of water are present in soil that exhibit a complex interrelationship. The proportion of exchangeable bases in a soil is obtained by the process of measuring concentration of hydrogen ions It is assumed that the proportion of other ions which can be held by the clay humus complex depends on the 'space' left by hydrogen ions. The proportion of free hydrogen ion in the soil solution is measured and stated as pH value.

Soils vary in pH from about 4, for strongly acid soils to about 10,

for alkaline soils that contain free sodium carbonate. The pH range for most agricultural soils is 5 to 8.5 pH; 7 is the natural value; values below pH 7 indicate an acidic soil and values above pH 7 indicate alkalinity. Table 3.3 shows the pH values of acidic and alkaline soils.

Table 3.3

pH Value Index

Very high acidity	Under pH 4.5
High acidity	pH 4.5 to 5
Moderate to high acidity	pH 5 to 5 5
Moderate acidity	pH 5 5 to 6 0
Slight acidity	pH 6 0 to 7 0
Neutrality	pH 7 0
Slight alkalinity	pH 7.0 to 7 5
Strong alkalinity	pH 7.5 and above

The cation exchange capacity of soil depends on the amounts and kinds of finely divided mineral and organic particles present. Sandy soils generally have low cation exchange capacities because of their smaller proportions of negatively charged material. Soil high in organic matter has substantial cation exchange capacities because of the large negative charge developed by humus. The pH value of soil is influenced by the soil water ratio, the electrolyte content and the carbondioxide level. The pH of soil varies considerably with its water content.

Saline and Alkali Soils

Saline and alkaline soils are those soils that have been harmed by soluble salts, consisting mainly of sodium, calcium, magnesium, chloride and sulphate and secondarily of potassium, bicarbonate, nitrate and boron. Salt affected soils are problem soils that require special remedial measures and management practices. Saline soils occur mostly in regions of arid of semiarid climates, while alkali soils are found in the humid climatic regions. Owing to the low rate of precipitation and high rate of evaporation, and inadequate drainage pattern, the salts accumulate in the soils of dry regions. Conversely, in the humid areas, the soluble salts and materials are leached out in

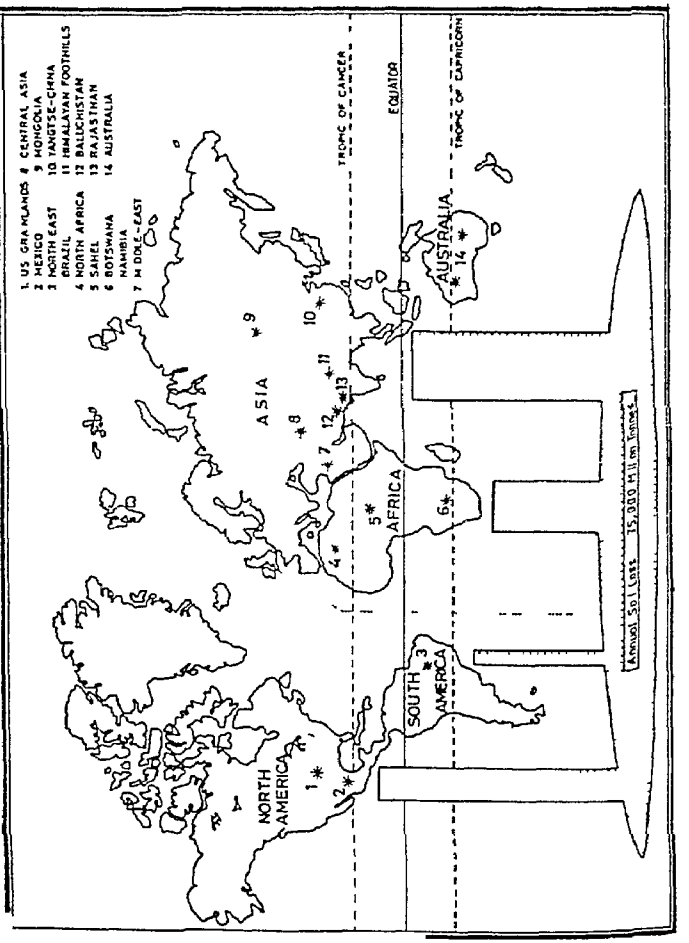
drainage water. The soluble salts are most commonly found in basins or depressed areas having poor or no drainage. They also accumulate in level areas, especially in the swampy and clayey soils

Saline soils are improved by establishing artificial drains if a high ground water table exists and by subsequent leaching with irrigation water to remove excess soluble salts. The improvement of alkali soil involves (besides drainage and leaching) the replacement of absorbed sodium by calcium or magnesium and the use of practices that develop good soil structure. The problem of salinity and alkalinity can be solved by use of manures and judicious selection and rotation of crops that can produce satisfactory yields. The salt tolerant crops, suitable for the saline affected lands, are barley, sugarbeet, cotton, bermuda grass, wheat grass, salt grass, birds foot, table sheets, kale, asparagus, spinach and tomato. Crops having low salt tolerance include radish, celery, beans, clover and nearly all fruit trees.

Soil Erosion

The removal of organic matter and plant food from the top layer and its leaching by the agents of denudation is called soil erosion. Soil erosion is caused by running water on sloping lands, by winds over the drier areas and in sandy soils of humid regions, and by waves on lake and ocean shore lines. Erosion is influenced by the nature of the soil, by the length and steepness of the slope, by the climate, especially by rainfall and by the crops grown. Some soils wash more easily than others. Erosion takes place with an accelerated rate on long slopes, particularly steep ones

The type of rainfall as well as the total amount that falls also influence soil erosion. Heavy rains cause flash run off that leads to severe erosion. On the whole, more erosion takes place in areas of high rather than low rainfall. Moreover, agricultural practices and the crops grown do have their influence on soil erosion, as the crops grown vary in the degree of exposure of soil. For example, crops like alfalfa, grasses, pastures and small grain crops are soil protecting, while cotton, maize, beans, cabbage, tobacco, potatoes and most of the other vegetables are soil exposing crops. In general more erosion takes place in the fields of soil exposing crops as compared to the soil protecting crops.



World Areas of Major Soil Erosion

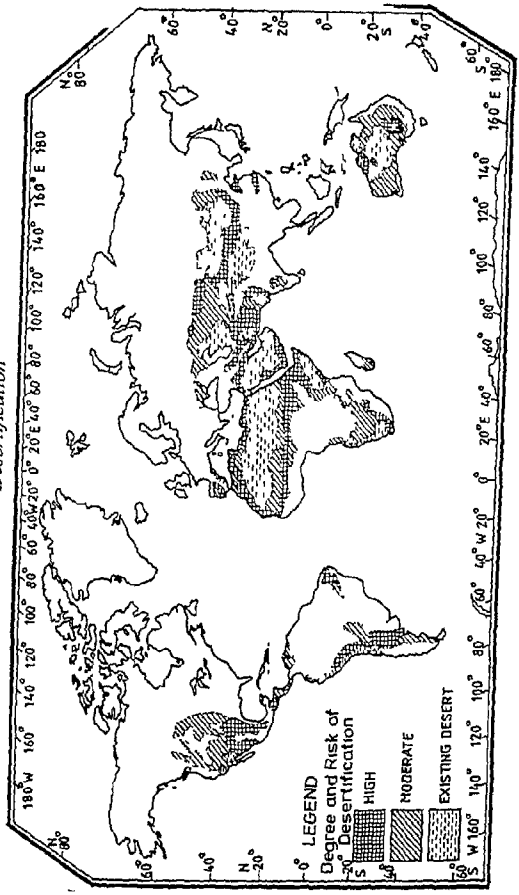


Figure 3.10
Desertification

In the semiarid and arid areas, owing to the non-availability of enough vegetative cover, erosion is done by the action of the wind. The development of vegetation cover and vegetation speed breakers can prevent soil erosion in the semiarid and arid regions. Overgrazing and devegetation also increase soil erosion. The congregation of livestock causes excessive grazing and trampling of the vegetation In the period of drought the resistance of grass is lowered, and the trampling and grazing of animals collecting around the available water cause much of the grass to die. The bare soil is then exposed to the action of wind. The mismanagement of forest and soil resources has increased the processes of desertification in the subtropical and semi-ariad temperate regions. The areas having accelerated rate of desertification have been shown in Figure 3.10.

Unchecked erosion gradually leads to poverty and undermines the strength of nations. Land, therefore, must be conserved while being used. Some of the important devices to check soil erosion are:

(i) rotate soil protecting crops;
(ii) application of manures and fertilizers;
(iii) divide soil into fairly narrow contour strips, where feasible;
(iv) develop terrace channels to carry water off slope to safe water ways;
(v) control gullies by keeping water out of them and check the movement of water in gullies by means of straw and vegetation;
(vi) develop a protective vegetation cover in the deserts;
(vii) plant crops in strips at right angles to the principal wind directions on sandy shores; and
(viii) plant beach grass with wild legumes and nitrogen fixing shrubs.

Since soils produce good yield and keep on doing so if they are well-managed and their health is well-looked after, they need more attention of the cultivators and the soil scientists.

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4 Socioeconomic Factors and Agriculture

The physical determinants discussed in the preceding chapter influence the agricultural patterns all over the world significantly. There are numerous sociocultural, economic, political, technological and infrastructural factors which also determine the agricultural land use, cropping patterns and agricultural processes. Of these factors, land tenancy, system of ownership, size of holdings, availability of labour and capital, religion, level of technological development, accessibility to the market, irrigation facilities, agricultural research and extension service, price incentives, government plans and international policies have a close impact on agricultural activities. The impact of these factors on the decision making processes of agriculture has been illustrated in the present chapter.

Land Tenancy

Land tenure includes all forms of tenancy and also ownership in any form. Land tenancy and land tenure affect the agricultural operations and cropping patterns in many ways. The farmers and cultivators plan the agricultural activities and farm (fields) management keeping in mind their rights and possession duration on the land.

In different communities of the world, the cultivators have different land tenancy rights. In the tribal societies of the shifting cultivators land belongs to the community and individuals are allowed only to grow crops along with other members of the community for a specific period. But among the sedentary farmers land belongs to in-

dividual farmers. In such societies it is believed that one who owns land he owns wealth. The ownership and the length of time available for planning, development and management of arable land influence the decision making process of the cultivator. Depending on the nature of tenancy rights he decides the extent to which investment on land could be made. For example, if the cultivator is the sole owner of the land, he may instal a tubewell in his farm and may go for fencing and masonry irrigation channels. But a tenant farmer or a sharecropper will not go for the long term investment in the field as after a short period of occupancy he will have to vacate the land and the real owner may cultivate that piece of land either himself or may lease out to other cultivator. In fact, a farmer who has the right of ownership, he has the freedom to choose a system of production and investment which improves the quality of land and gives him increasing capacity to borrow money.

The cropping patterns and farm management are also dependent on the duration of time for which the land is to remain under cultivation For example, among the shifting cultivators (*Jhumias* of northeast India), the allotment of land to the cultivator is normally done for one or two years, depending on the fertility of the land. The hilly terrain, the limited rights of the occupant and poor economic condition of the tillers hinder the development and efficient management of land. Since the land belongs to the community and not to the individuals, this type of land tenancy prevents the energetic, efficient and skilled individuals of the community to invest in the farm. Under such a system individuals are also unlikely to put much efforts or invest more money on the improvement of cultivated land as the field is allotted by the community for a short period. Under this type of land tenancy there is no incentive to individuals to improve the agricultural efficiency and productivity of the land. In the erstwhile Soviet Union the yield per unit area of the Kolkhoz and Sovkhoz was much below to that of the small holdings (about one acre) given to each household. It was reported that the per acre yield of the privately managed small holdings was three to four times more to that of the state farm and the collective farms.

Contrary to this, a tenant having a lease for a longer period, has considerable incentive to make his own improvements in drainage,

irrigation channels, fencing and soil sustainability practices. Such leases are, however, rare. The tenancy system of short duration lease leads to insecurity for tenants. In India, the fear of landlords regaining control of farms has led to restrictions on long term letting. This has resulted into eleven months lease system. In the annual leasing system, however, very high rents are obtainable. In the short leasing system, it has been suggested that it enables a farmer to adopt his holding to his immediate needs but there is a strange temptation for a person who is working on the land only for one year to extract from the land as much as he can and put back the minimum Consequently, the health of the soil due to unscientific rotation of crop is lost.

In India, at the time of independence (1947), there were two main tenure systems, i.e., the *zamindari* and the *raiyatwari*. These systems determined the relations between land on the one hand and the interested parties, the government, the owners and the cultivators, on the other. In the *zamindari* system, the land property rights were conferred upon persons who were avowedly non-cultivators but had sufficient influence in the region to collect land revenue from the cultivating peasantry. This was necessary at a time when the foreign government was not firmly established and direct control of land revenue and contact with the peasants was difficult. Owing to the *zamindari* tenure system, the real cultivators and tillers were exploited. They were, therefore, not interested in making investment in the land. Owner-cultivators who have a good deal of incentives to invest in land to improve the techniques of cultivation and to enhance productivity were discouraged. The tenant-cultivators in such a system face major disincentives like the fear of eviction, the insecurity of tenure, the rack-renting practice, the high rents and the inadequate surplus to invest.

In Southeast Asia, Latin America and parts of Southern Europe a system of land tenure known as '*metayage*' is very widespread In its simplest form it is a copartnership between the owner who provides land, equipments, buildings, seeds, fertilizers and the *metayer* (cultivator) who provides labour and stock in return of a fixed share of the produce. The system sometimes involves pure sharecropping, i.e., there is no fixed rent, but the tenant cultivates the land and gives the owner a share, often 50 per cent of the agricultural produce. In north-

ern India, this system is known as '*Batai*'. This tenural system gives the tenant some protection from fluctuations in productions and crop prices and is usually preferable to fixed cash tenancies in which a tenant tends to fall progressively deeper into debts, whenever income from his crop falls below the outgoing rent. The traditional method of covering the deficit is by having recourse to a moneylender—a role used to be performed by the Jews in Europe, Greeks in the Middle East and the Bohras and Baniyas in India. In the rural areas of the developing countries, the moneylenders often charge exorbitant rates of interest and wield considerable power.

Size of Holdings and Fragmentation of Fields

It is not only the land tenancy and the system of ownership which influence the agricultural and cropping patterns, the size of holdings and fragmentation of fields also have a close bearing on agricultural land use patterns and yields per unit area. In the densely populated areas of the developing countries the size of holdings is generally very small. The size of holding and the size of farm decide the degree of risk that a farm operator may bear. In general, larger the size of the farm, greater the capacity of the farmer to take the risk and vice versa. This, in turn, would affect the extent of specialization and also the nature of technology and equipments (tractors, thrashers, harvesters, etc.) to be used.

In India, the average size of holding is very small. In fact, about 70 per cent of the total holdings are below one and a half hectares The average standard size of holding that may give better agricultural returns cannot be maintained because of the fast growing rural population and the prevailing law of inheritance. The law of succession in the countries like India, Pakistan, Bangladesh and Sri Lanka results in the subdivision and fragmentation of holdings. According to the law of inheritance in these countries, the property of the deceased is equally divided among the male heirs. Each son generally insists on having a share from each location and from each piece of land, resulting into further fragmentation of land. It is a wasteful and uneconomic method of land utilization in which improved agricultural practices cannot be adopted. The disadvantages of fragmentation of holdings are well known. It puts a large proportion of land outside the possibility of effective cultivation or economic development. The

small fields are difficult to work with modern machinery and tractors etc. In the opinion of agricultural economists, the fragmentation of holdings is a great obstacle and one of the major deterrents to economically viable cultivation. It results in wastage of land, labour and material inputs. It is responsible for increased overhead costs, including even the cost of production resulting in low returns from agriculture. The division of holdings may be socially justifiable but economically they are not viable.

Consolidation of Holdings and Operational Efficiency

In order to overcome the disadvantages of fragmentation of holdings, consolidation of holdings has been done in many parts of the country. The advantages of consolidation of holdings are manifold. Important amongst them have been explained below.

The fragmentation of holdings makes the efficient management and supervision of the farm operations difficult. It causes considerable waste of labour of the cultivator and his plough cattle. Land consolidation makes it necessary for him to look after the crops and put up a fence around the holding. It also enables the farmer to construct a farm house on the holding and shed for his cattle and thus exercise efficient supervision and management. The use of tractors and machinery also becomes possible in the case of substantial holdings. All these advantages are reflected in inputs cost and increase in production. The area wasted in embankments and boundaries in scattered holdings is released for cultivation after land consolidation. The farmer can take effective steps in the areas where soil erosion is a problem Moreover, it helps in the development of better road linkages. The consolidation of holdings would, however, be fruitless if the advantages derived from the operations were to disappear as a result of the acts contrary to the purpose of consolidation leading to fragmentation of the consolidated properties.

Apart from solving the problems of consolidation of holdings, there must be a size of farm below which its output is too small to maintain the family, at whatever is considered to be the reasonable standard of living. The experts agree that under the average agroclimatic conditions in India a farm well above two hectares will be capable of reconciling the various minimal of income and employment.

The solution of the problem may partly be found in the agricultural land ceiling. The basic idea of the agricultural land ceiling is to ration out land in such a way that above a certain maximum limit, the land is taken away from the present holders and is distributed to landless or small holders according to some priorities. The objectives of ceiling strategy are to increase agricultural productivity of arable lands with a much more equitable income and power distribution and with a new structure suited for technological changes.

Since independence, in India, a number of steps have been taken to make structural changes in the agrarian societies and land reforms. The Kumarappa Committee, also known as the Congress Committee of Agrarian Reforms, recommended comprehensive measures for land distribution, creation of basic holdings, tenancy reforms, organization of small cooperative reforms and minimum agricultural wages. But so powerful was the lobby of the big and middle class peasants that the recommendations were shelved. The enthusiasm for land ceiling is much greater now, but it is doubtful whether the results will be encouraging. As a matter of fact, land reform is costly and has profound social consequences, but what is socially just may not be economically efficient or politically tenable.

Labour

The availability of labour is also a major constraint in the agricultural land use and cropping patterns of a region. Labour represents all human services other than decision making and capital. The availability of labour, its quantity and quality at the periods of peak labour demand have great influence on decision making process of the farmer The different crops and agrarian systems vary in their total labour requirements. The labour inputs vary considerably round the year for most of the agricultural enterprises with the result that many farmers employ a mixed system of production in order to keep their labour fully employed. Even then, in many parts of India, seasonal unemployment remains on most of the holdings, while during the peak periods of crop sowing (rice, wheat, sugarcane, vegetables and potatoes) and harvesting, there occurs acute shortage of labour which influences the sowing and harvesting operations and thereby affect the decision of a farmer whether to grow or not a crop. Many of the cultivators of western Uttar Pradesh (Saharanpur and Muzaffarnagar dis-

tricts) have given up the cultivation of rice owing to the non-availability of workers at the times of transplantation and harvesting. The farmers of Punjab are increasingly dependent on Bihari labourers for the harvest of their wheat and rice crops.

In many of the developed countries like the United States, Germany, Japan and U K, and in some tracts of the developing countries like the plains of the Punjab and Haryana in India, the rapid loss of farm labour is becoming a matter of great concern. There are two basic reasons for the decline of agricultural labour, especially in the developed countries. Firstly, the industrialized nations offer alternative and financially attractive employment. Secondly, there are greater leisure opportunities for the industrial workers. In India, very few job opportunities occur outside agriculture which lead to unemployment of agricultural landless labour and small size farmers. Thus, the availability of labour has a direct impact in the labour intensive cropping patterns and its importance is much felt in the plantation estates and the subsistance paddy farming typology.

Capital

Capital subscribes definite limitations to the selection of crops. All agricultural inputs like the livestock, irrigation, seeds, fertilizers, insecticides, pesticides, feeding stuffs, labour, purchase of land, machinery, carts, vehicles, various agricultural equipments, buildings, fuel and power, sprays, veterinary services and repairs and maintenance require capital. All the farmers make their decisions on the basis of capital to invest. The traditional way of cultivation is giving way to the market oriented crops which need more capital for getting higher returns. In the underdeveloped countries, moneylender is still the main source of finance in the remote rural areas and he advances money to the farmers at a high rate of interest with the intention of exploitation. Moreover, the permanent investment in agricultural system like plantation (tea, coffee, rubber) put a great restriction on the selection of alternative cropping patterns.

The development of irrigation facilities without capital is not possible. The role of irrigation in the areas of erratic rainfall, arid and semiarid regions is quite significant. Its importance has substantially increased after the adoption of High Yielding Varieties(HYV) in the developing countries. Irrigation not only enhances the yields of

crops, it also helps in the intensification and horizontal expansion of agriculture. The deserts like the Nile valley, Turkmenistan, Uzbaikistan, and parts of Thar desert have been made green, growing cotton, cereals, vegetables and citrus fruits with the help of irrigation. The development of irrigation which is one of the primary bases of agriculture needs enormous amount of capital.

Mechanization and Equipments

The technological changes including the use of modern hand tools, animals drawn implements, tractors, thrashers and more economic patterns of farm management play a vital role in the selection of crops grown and decision making at the farm level. These changes help in improving the crop yields. The improvements occur partly from the use of more effective equipment but also, because mechanization makes it possible to carry out farming operations more quickly and at the precise time calculated to maximize outputs. In the plains of the Punjab and western Uttar Pradesh, for example, the increasing substitution of tractors for bullocks has greatly shortened the time, the farmer has to spent on the ploughing and sowing of the *kharif* and *rabi* crops. This enables the farmers to cultivate their fallow land before it becomes infested with weeds in the summer season—a practice which was not feasible when oxen drawn plough was used. The result was a substantial diminution of weeds and increased cereal crop yields. More far-reaching is the impact of rice planting, and harvesting machines in Japan and China, where traditional methods entail the putting in of every single seedling of rice by hand at an immense cost and back-breaking toil. In China, simple machines, constructed mostly of bamboo, wood and a few metal parts, have been in use since 1958. The machines, under normal conditions, do twenty times the amount of work of a hand planter, thus greatly shortening the time needed to plant the rice crop. The deployment of such machines is specially important for areas with two or more than two crops a year. The improved tools and farm implements can change appreciably the cropping patterns, cropping intensity and crop combinations resulting into high agricultural returns. In fact, tractors have largely transformed the agricultural landscape of the Punjab and Haryana in India.

Transportation Facilities

Transportation facilities also have a direct bearing on the cropping patterns of a region. Better transport linkages are advantageous because of the economies in farm labour and storage costs which they make possible. These savings in turn help to make it economic for farmers to buy fertilizers and better equipments. Better transport also makes it possible for farmers to put their less accessible land to more productive use. In areas inadequately served by the modern means of transportation, the surplus produce is often damaged either by adverse weather or by rats, pests and diseases. In the hilly states of northeast India (Meghalaya, Mizoram, Nagaland, Manipur, Arunachal Pradesh) costly crops like ginger, pineapple and banana are grown in surplus quantities but the poor means of transportation and inadequate road linkages deprive the cultivators of most of the profits. Contrary to this, in the United States, the truck farming is done at distant places from the big cities and markets as the farmer is able to supply his perishable crops (vegetables, flowers and fruits) to the distant markets within a short period of time at a reasonable rate of transportation.

Marketing Facilities

The accessibility to the market is a manor consideration in the decision making of the farmer. The intensity of agriculture and the production of crops decline as the location of cultivation gets away from the marketing centres. This is particularly noticeable when a bulky but low value crop has to be transported to the market. If it takes much time to send the produce, especially at the peak time, to the market when the farmer could have been profitably employed in other activities. The marketing system also influences the decision making of the farmer. In most of the countries the agricultural commodity markets are controlled by the buyers rather than sellers. The farmers, however, can influence the market by storing their products on the farms or in cold storages until prices are remunerative. But since the number of buyers is lesser than the number of sellers and the cultivator is not financially well off to store the crop, the bargaining position of the farmer remains weak. The fluctuations in prices of agricultural produce many a times compel the farmers to change the

cropping patterns. The farmers of the western Uttar Pradesh, for example, shifted from sugarcane cultivation to cereals and potato cultivation from 1977 to 1979, but the prevalent attractive prices of sugarcane have motivated the farmers to go for the sugarcane cultivation in the region. In 1995-96 the farmers of western Uttar Pradesh had an adverse experience in the case of sugarcane which they could not sell at remunerative price and many of them had to burn their crops in the fields. The uncertainty in marketing is bound to compel the farmers to shift from sugarcane to some cereal or fodder crop cultivation.

The size of market may be an important factor because a market may encourage transport and handling innovations together with economic scale. Wheat has a great international market because it is convenient to handle even though it is a bulky commodity. Great Britain which imports about 8 million tonnes (metric tonnes) of wheat and other cereals has encouraged the development of special carrying ships, the opening of new water routes, such as the Hudson Bay from the Canadian wheatlands and the construction of new railway systems in the country.

Government Policies

The agricultural land use and cropping patterns are also influenced by the government policies. The fluctuations in the price of sugarcane, wheat, oilseeds and legumes provide impetus or disincentives to the cultivators to grow these crops. Under certain political conditions, the government may stop the farmers to grow certain crops. In the socialist countries like Russia, Rumania, Bulgaria, Albania, Cuba, etc., the combination of crops, their rotation, areal strength and mode of disposal are completely controlled by the governments. In developing countries, like India, the government announces the price of various cereals and cash crops well in advance so that the farmers may devote their agricultural lands to different suitable cereal and other money fetching crops.

Apart from the domestic policies, the governments enter into international agreements to supply certain agricultural commodities to each other in order to maintain the balance of trade The British government imports a substantial quantity of dairy products from New Zealand and Australia. Canada and Argentina export wheat while Cuba, Indonesia and India are the exporters of sugar. These interna-

tional agreements have a close bearing on the cropping patterns of different countries.

Religion

The religion of the cultivators has also influenced the agricultural activities in the different parts of the world. Each of the major religions has certain taboos and the use of certain agricultural commodities is prohibited in each of them. The Khasis and Lushais of Meghalaya and Mizoram are not interested in dairying as milk and milk products are taboo in their society. Piggery is prohibited among the Muslims. Hindus hate slaughtering, while Sikhs never go for the cultivation of tobacco. The productive and adequately irrigated loamy tracts of western Haryana (including Bhiwani, Hissar, Mohindergarh, and Sirsa districts) are ideally suited for the cultivation of sunflower. It is a short duration highly remunerative cash crop which matures in only 60 days. For the last two decades, the farmers in these districts were obtaining two sunflower crops in a year in between the *kharif* and *rabi* crops. Unfortunately, the population of *Neelgai* (an antelope) has multiplied in this region significantly. This antelope which is being considered as sacred cow relishes the plant of sunflower and prefers to stay in or around its fields. The *Neelgai* menace has forced the cultivators of Haryana to give up sunflower cultivation It is one of the unique examples in which the wild animals have influenced the cropping pattern significantly and the progressive farmers of Haryana are being deprived of a highly remunerative cash crop. Keeping into mind the religious sentiments of the Hindu farmers and the importance of sunflower as a cash crop (oilseed), the government should evolve a suitable strategy to check the fast growth of *Neelgai* population, failure to which the process of agricultural development in the region may be adversely affected.

In brief, the socioeconomic and politicocultural factors, especially land tenancy, landownership, size of holdings, fragmentation of fields, availability of labour, capital, accessibility to the market, storage facilities, government policies, international agreements and religion of the cultivators substantially influence the agricultural patterns and agricultural land use of a region.

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5 Agricultural Systems of the World

The identification, description and explanation of farming types and agricultural systems have been a long concern of geographers. An area or region with similar functional attributes is termed as an agricultural system. Some of the geographers have used agricultural typology and agricultural system as a wider term which emphasize on the functional attributes. An agricultural system may be a single farm, or group of interrelated farms having similarities of agricultural attributes. The variations in the attributes of agricultural systems are the results of terrain, climate, soil and sociocultural and ecopolitical factors. Since there is great diversity in the physical and non-physical factors over the earth surface, the delineation of agricultural systems is a tedious task. The demarcation of agricultural systems is also seriously constrained by the non-availability of reliable data on the various aspects of agricultural patterns. The first scientific attempt for the delineation of agricultural systems was made by Derwent Whittlesey in his paper 'Major Agricultural Regions of the Earth' published in 1936 in the *Annals of Association of American Geographers* (Vol. 26: 199-240).

Whittlesey, in his monumental paper, delineated the agricultural systems of the earth on the following five characteristics of agriculture:

4. The disposal of the products for consumption (i e., whether used for subsistence or the farm or sold off for cash or other goods).
5. The ensemble of structures used to house and facilitate the farming operations.

These five basic functional forms of agriculture can be measured and observed by an experienced geographer. The measurements and observations can be used for quantitative definition and delimitation of the boundaries of agricultural regions. The operation of these on a global scale is difficult, since the data for most areas are not sufficient and for many areas agricultural censuses are neither available nor accessible. Whittlesey, however, has not taken some of the relevant indicators like land tenancy, landownership, size of holdings, fragmentation of holdings, the religion of the cultivators, the forms of the government and government policies about agriculture. The approach has, therefore, subsequently been modified by geographers and they included several more relevant indicators in the demarcation of agricultural systems of the world

With the help of the above indicators, Whittlesey has identified the following thirteen types of agricultural systems:

1. Nomadic herding
2. Livestock ranching
3. Shifting cultivation
4. Rudimentary tillage
5. Intensive subsistence tillage with rice dominance
6. Intensive subsistence tillage without paddy dominance
7. Commercial plantation
8. Mediterranean agriculture
9. Commercial grain farming
10. Commercial livestock and crop farming
11. Subsistence crop and stock farming
12. Commercial dairy farming
13. Specialized horticulture

A brief account of these agricultural systems is given below un-

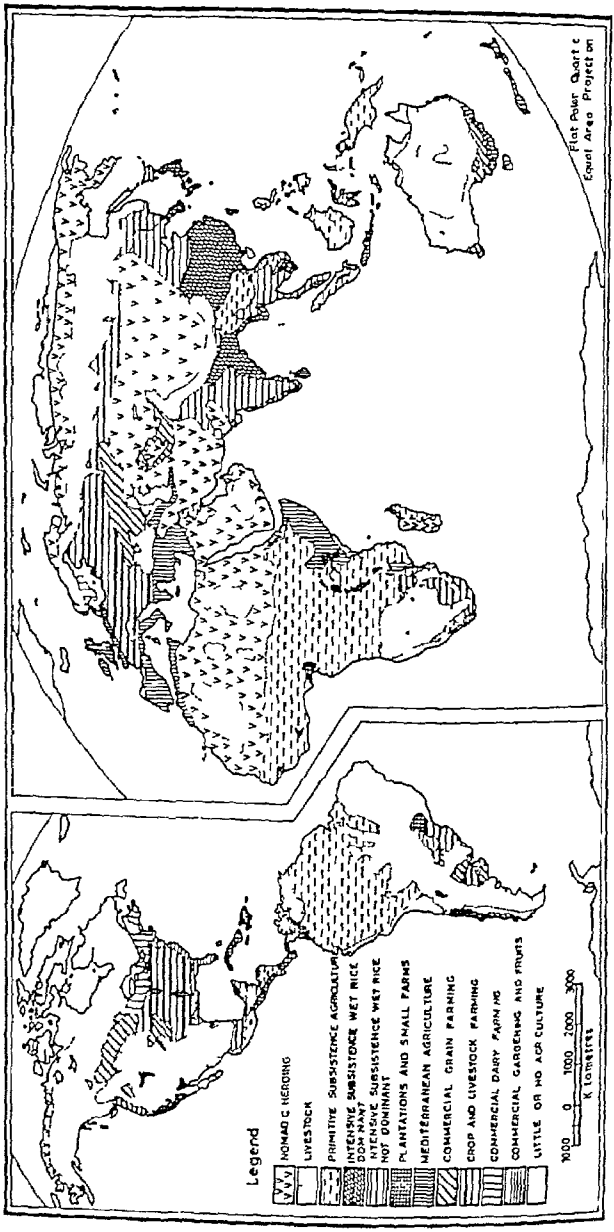


Figure 5.1
The Agricultural Regions of the World (after D. Whittlesey)

der separate heads.

Nomadic Herding

Nomadic herding is an ecological or near ecological system of agriculture. It is carried on mainly to produce food for the family and to fulfil the needs of clothing, shelter and recreation. It is the simplest form of pastoralism. The nomadic herders are dependent on sheep, cattle, goats, camels, horses and reindeers for their livelihood. Herds composition vary from one region to another, but throughout the dry belt sheep and goats are the most common animals and cattle are the least common as they do not like hot and arid climates. The length of stay of the nomads at one place and the direction of their movement are governed by the availability of water and natural forage. The nomad's and herder's house is generally a tent which can be transported easily.

The arid and semiarid areas of the world, from the shores of Atlantic in Africa to the steppes of Mongolia, have been occupied by the pastoral nomads for the last more than 3000 years (Grigg, 1978). Nomadic herding, at present, is mainly concentrated in Saharan Africa (Mauritania, Mali, Niger, Chad, Sudan, Libya, Algeria), the southwestern and central parts of Asia, the northern parts of the Scandinavian countries (Norway, Sweden, Finland) and northern Canada. All these areas are sparsely populated. Owing to the non-availability of water, these areas are unsuitable for the cultivation of crop but the people are utilizing these ecosystems for rearing or grazing of livestock.

The nomads graze their herds on native grasses and migrate from one place to another in search of grass and water. In the poor grazing areas sheep and goats constitute the mains herds; horses, mules and donkeys are common herds in the semiarid and temperate grasslands; camels and yaks are important in the deserts and plateaux respectively; while reindeer is important in the Arctic region. At the depletion of pastures, the herders have to move their herds to new pastures. Thus, after every few days, they have to migrate with their herds. With the change of season these nomads migrate to long distances in the plains and from low lands to high lands.

The size and composition of herds vary a great deal amongst pastoral nomads. Livestock are generally owned by families, and fami-

lies grouped in tribes, but the migratory unit is generally smaller than the tribe. In the Middle East, each migratory unit consists of five or six families. Each family requires about 25-60 goats and sheep or 10-25 camels for minimum subsistence.

The food of nomads is mostly of animal origin, i.e., milk, cheese, curd, butter and meat. Despite the importance of animals as a source from which most of the material wants are supplied, herds in the absence of controlled breeding, tend to be of a low grade with some exceptions in the case of horses and camels. Though the nomadic herding areas are well scattered in the different semiarid parts of the world, they can be classified into the following three regions : (i) Central Asia, (ii) Southwest Asia and Northern Africa, and (iii) Tundra (Fig. 5.2).

(i) Nomadic Herders of the Central Asia

The nomadic herding areas of Central Asia include Mongolia, Tibet, Sinkiang, Turkmenistan, Kazakistan, Uzbaikistan and the Kirghizia steppes. These are the traditional lands of nomads. The Kazaks, Kirghiz and Mongols are among the principal pastoral nomads. These nomads in search of fodder and water migrate to the foothills, high valleys, plateaux, broad basins and high mountains of Central Asia. In Central Asia, owing to the scarcity and uncertainty of rains, cultivation of crops with success cannot be done, and facilities of artificial irrigation are generally not available. Therefore, cultivation of crops is not profitable. Moreover, in Central Asia, the climate, soil and natural grasses have a great diversity. As a result, the life of nomadic herders of Central Asia is attached to herds which flourish well in the grasslands of the region.

(ii) Nomadic Herders of Southwest Asia and North Africa

The nomadic herding region of Southwest Asia and North Africa consists of Iraq, Iran, Syria, Jordan, Saudi Arabia, UAE, Plateau of Anatolia (Turkey), Sudan, semiarid fringes of the Sahara desert and the high lands of eastern Africa (Fig. 5.2). In this region, the rainfall is scanty and in many parts the average annual rainfall is less than 25 cm (10 inches). In the semiarid climatic conditions only grasses of small size grow as the major natural vegetation.

The scarcity of rainfall leads to paucity of pastures. These condi-

Figure 5.2
Grazing Areas of the World

tions are best suited for sheep and goats as they can survive even under the drought conditions and poor pastures for some time. This region, therefore, is one of the most important goats and sheep rearing areas of the world. Angora goats, famous for their silky wool, known as *mohair*, are specially numerous in Anatolia (Turkey). The camel is also more important here than anywhere else as it can live without water and fodder in the hot deserts for some days and can endure hardships. In the highlands of eastcentral Africa the Masai herder tribe graze their sheep and goats in the short grass pastures of the savannas in the valleys in winters and they migrate to the rich pastures of tall grasses of the high plateaux and mountains in the summers.

(iii) Nomadic Herders of Tundra

On the southern margins of Tundra, there are certain nomadic herders, e.g., Lapps, Yakuts and Eskimos. These herders have adjusted themselves to the food supply of reindeer. In the northern parts of Norway, Sweden, Russia and Finland such herders constitute a significant part of the population. During the short summer they live on the grassy mountains and in autumn they migrate along with their herds in coniferous areas of the south in order to meet the fodder requirements of their herds and to protect them from the freezing conditions of the Tundra climate. Many a times they cross the international boundaries to get fodder and to avoid starvation. For the Lapps of Norway, Sweden, Finland and Russia, special provisions of international law have been made which allow them to migrate from one country to another at the time of fodder and food shortage.

In the present century a large change has occurred in the life style of nomadic herders. Nomads have suffered owing to reduction of their grazing areas as livestock ranching has moved into drier regions, and pressure has been put on many communities to adopt sedentary ways of life, notably in the socialist countries where collective and state farms have encroached the natural grasslands of the nomads. In the semiarid areas sedentarization has been started, and the respective governments are planning to bring more nomadic grazing areas under agriculture. In general, the population of nomadic herders has been decreasing and areas dominated by them in the past have been shrinking. Moreover, it appears that true nomadism is likely to survive in few pockets of small isolated areas.

Livestock Ranching

Livestock ranching is carried on in the regions with relatively flat surface and plains where natural grasses grow luxuriously. It is mostly practised in the temperate and tropical grasslands. The leading areas of commercial grazing in the temperate grasslands include the plains and plateaux of North America, Australia, New Zealand, South Africa, and the Andes moorlands (Fig.5.2). The average annual rainfall in the temperate grasslands ranges between 25 cm and 75 cm and has great seasonal fluctuations.

The movements of stock are normally confined to the ranch although there may be seasonal movement or transhumance to distant pastures. The ranch is a permanent base Ranching methods are the outcome of European adoption to environments demanding very extensive forms of agriculture. Cropping is limited to provisions of fodder for periods when natural grazing is not available or is inadequate. The provision of better supplies of fodder, together with water control and improved care of stock, are the principal ways of increasing the yield of these farms.

The temperate grasslands of North America, called 'prairies', lie in the western parts of the United States, the plains of Canada and north Mexico (Fig.5.2). This is one of the most advanced commercial grazing region of the world. In the prairies grasslands, the relatively small amount of rainfall is ample to support short grasses Not only the amount of rainfall is limited, but the amount received in any one year is also subject to great variations and periods of drought sometimes become of several years duration which hinder the cultivation of crops. The attempts at dry farming have, therefore, been generally unremunerative except in the more favoured portions of the prairies grasslands. Because of the climatic constraints these grasslands are in general use for grazing.

The prairies grasslands have thousands of ranches with more than 1000 acres each. The cattle include the white-faced Hereford cattle breed, the black and white Friesian cows, the Jersy cows and the superior breeds of sheep which provide excellent quality of wool in large quantities. Every year, millions of cattle and sheep are fattened and transported to large slaughter houses.

Livestock ranching in South America is practised in the temper-

ate grasslands of Argentina. Uruguay and south Brazil. In Argentina, the pampas undulating lands between the Parana and the Uruguay rivers. Patagonia and Tierra del Fuego are excellent commercial grazing lands. The pampas receive about 50 cm to 100 cm average annual rainfall. well spread throughout the year and has cool climatic conditions. Under the prevailing agro-climatic conditions of pampas a fair growth of grasses like alfalfa enables the ranchers to adopt commercial grazing as their main occupation. The ranches are separated from each other by fencing and thus the stocks are not allowed to mix up. The alfalfa grass when planted supports one grown up cattle on every two acres. while in the natural alfalfa pastures four to seven acres are required to feed one cattle. The occasional summer drought and disease of cattle are the main problems of the temperate commercial grazing regions. Argentina has about 5 per cent of the world's cattle population but most of them are kept for beef. Despite an enormous home consumption of beef. Argentina has still a large surplus for export and is the biggest exporter of meat in the world.

Three-fourth of the total area of Uruguay is devoted to cattle and sheep grazing. Uruguay exports large quantities of canned, frozen. dried beef and wool, hides and sheep skins to Europe.

South Brazil has good pastures and its climatic conditions permit the year round grazing. South Brazil maintains about one-fourth of the cattle and two-third of sheep of the Brazil. South Brazil supplies chilled beef to the European countries.

Australia is also an important commercial grazing country. It has about 120 million sheep and supplies nearly one-half of the world's wool exports. The major grazing areas of Australia lie in the southeast and western Australia. In the provinces of New South Wales. Victoria and South Australia. excellent breeds of mutton sheep graze on natural pastures. To the west of the mountains in the province of Queensland and Western Australia on the semiarid grasslands the sheep are mostly of the wool breeds. In the semiarid areas. the shortage of water is a problem for which the government has constructed reservoirs and wells to utilize the ground water resources. The explosion in the population of rabbits and wild dogs are major problems of sheepmen. The long fences have been constructed to stop them from spreading. The problem of rabbits is. however. still to be solved. De-

spite these handicaps, the temperature grasslands of Australia are among the leading commercial grazing areas of the world.

New Zealand is one of the developed countries of the world. Its development and progress almost entirely depend on the sheep and cattle grazing industry. There are about twenty sheep and two cattle per person. In New Zealand rainfall is well distributed throughout the year, the climate is cool and moist which provides plenty of grass and water to sheep and cattle. The mild temperature permits grazing throughout the year while the mountainous topography is conducive to the mutton and wool varieties of goats and sheep. In New Zealand cattle are kept not on huge open ranches but on fairly small farms and carefully fed to give quality meat. New Zealand supplies about two-third of the world export of mutton. It is also an important exporter of wool, beef and butter.

Near the southern edge of South African plateau lies a region of temperate grassland. It is a broad level area receiving rainfall between 35 cm and 75 cm per annum. Most of the rain occurs in summer months Sheep grazing is the major occupation. Some of the beef and cattle products are exported to the European countries.

Livestock ranching have all suffered from overgrazing. At times most of these areas experience disastrous droughts. Improvements in the breeds of stocks, prevention of overgrazing and conservation of water resources are, however, necessary if these regions of temperate grasslands continue to develop the world trade in animal products.

Commercial Grazing

Commercial grazing in the tropical grasslands is carried on in savanna. These lands receive about 100 cm of average annual rainfall. The savannas are commonly laced with forests and lie between the regions of dense tropical forests and the deserts which border their drier margins All savanna grasslands have a marked seasonal periodicity of rainfall. During the short rainy summer season rainfall may be very heavy, but during the much longer dry season it is always light. These are the conditions which permit the growth of grass but do not favour the development of forests.

The grasses of savanna are very tall, often higher than a man's height and sometimes they even touch the lower branches of the

small trees. The tall grass is hard and tough and makes a poor feed for cattle. Thus, the pastures are poor except for a limited period of time after the rains when new grass shoots up. Insects, pests disease among men and animals, warm climate, labour shortage, distance from market and poor connectivity are the major barriers in the development of commercial grazing in tropical grasslands. Nevertheless, commercial grazing of cattle in tropical lands is an important activity in Llanos (South America), southern Brazil, Sudan and the savanna grasslands in southern parts of Africa. Despite the large number of cattle grazed, there is, however, little or no surplus production in the tropical grasslands. The temperature, tall hard grasses are not suitable for the good breed of cattle, sheep and goats. Even with the improvement in cattle and sheep breeds, it is believed that the tropical grasslands will always remain at best only in second rate areas of commercial grazing.

Shifting Cultivation or *Jhuming*

The history of shifting cultivation is as old as the history of agriculture itself. On the basis of archaeological evidences and radio-carbon dating, the origin of shifting cultivation could be traced back to about 8000 BC in the neolithic period which witnessed the remarkable and revolutionary change in man's mode of production of food as from hunter and gatherer he became food producer. The prehistoric shifting cultivators used fire-stone, axes and hoes, while in the present-day shifting cultivation the stone tools have been replaced by digging sticks, iron tools, iron digging sticks, *daon*, hoe and knives.

Shifting cultivation is the primitive form of soil utilization, usually of tropical rain forests and bush areas of Central Africa, Central America and Southeast Asia (Fig. 5.3). The farmers grow food only for his family in this agriculture system. Some small surplus, if any, are exchanged or bartered (exchange of commodity for commodity) or sold for cash in the neighbouring markets. The shifting population is thus self-reliant with a high degree of economic independence and the resultant economy is almost static with little chance of rapid improvement.

Shifting cultivation is called by different names in different parts of the world. It is generally known as 'slash and burn' and 'bush fal-

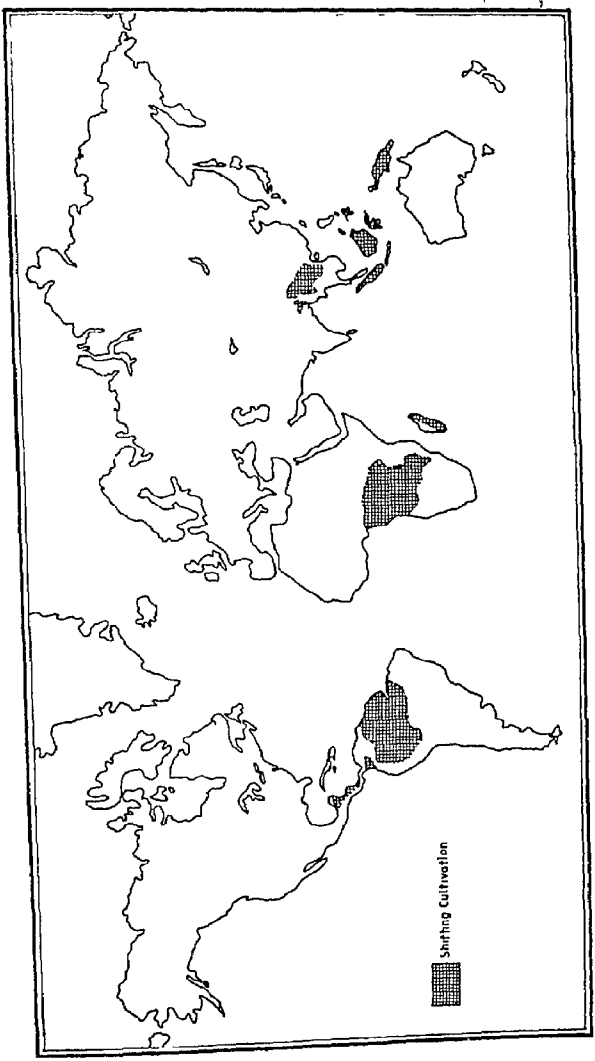


Figure 5.3
World:Shifting Cultivation

in Vietnam, *Conuco* in Venezuela, *Roca* in Brazil, Masole in the Congo and Central Africa. It is also practised in the highlands of Manchuria, Korea and southwest China. It is known as *Jhum* or *Jum* in the hilly states of Northeast India, as *Podu*, *Dabi*, *Koman* or *Bringa* in Orissa, as *Kumari* in Western Ghats, as *Watra* in southeast Rajasthan, as *Penda*, *Bewar* or *Dahia* and *Deppa* or *Kumari* in the Bastar district of Madhya Pradesh.

Shifting cultivation has been described as an economy of which the main characteristics are rotation of fields rather than rotation of crops, absence of draught animals and manuring, use of human labour only, employment of dibble stick or hoe, and short period of occupancy alternating with long fallow periods. After two or three years the fields are abandoned, the cultivators shift to another clearing, leaving the old one for natural recuperation. This explains the use of the term 'shifting cultivation'. It, however, does not imply that the homestead are also shifted to the new site along with the shifting cultivation. More often than not, the homestead are not shifted.

Shifting cultivation, though a rudimentary technique of land and forest resource utilization, represents an intricate relationship between ecology, economy and society of a region. The *jhum* fields, their surrounding forests and natural areas provide two alternative sources of subsistence to the dependent population. In case the *jhum* crops are not good, the forests could be trapped by them for augmenting their food supplies. Moreover, the shifting cultivators keep pigs and swines which feed on the vegetable wastes and inferior grains. The pigs function as buffer stock which are used during the periods of scarcity and they are also used at the time of festivals and feasts. Shifting cultivation is a great catalytic force for community life. In such societies, natural resources (land, forests, water) belong to community and not to the individuals.

The social organization of the people is built around the concepts of community ownership, community participation and communal responsibility. The basic axiom of life is "from each according to his capacity and to each according to his needs". Thus, in the society of shifting cultivators, the old, infirm, women, widows and children have an equal share, and each member of the society plays a role according to his physical and mental abilities.

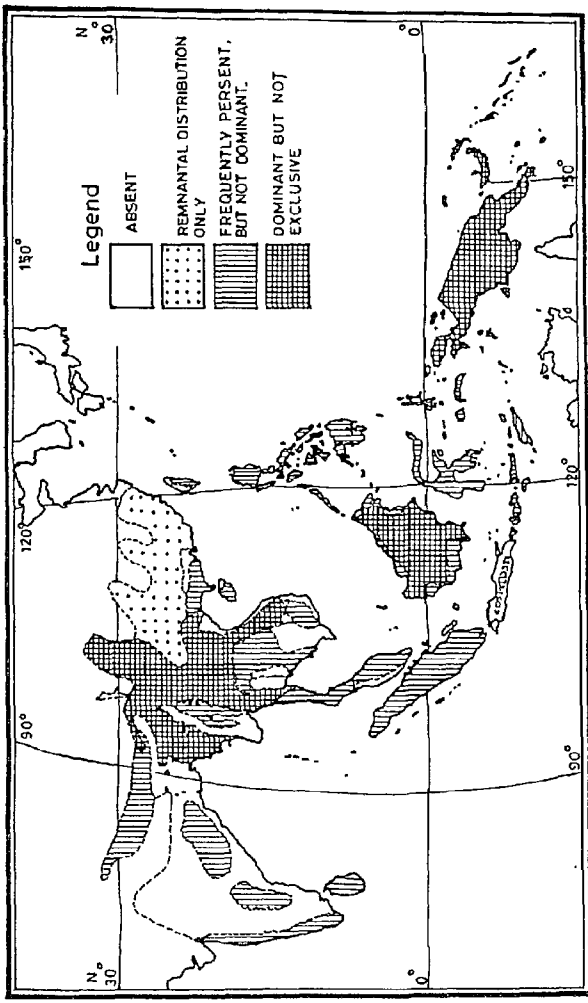
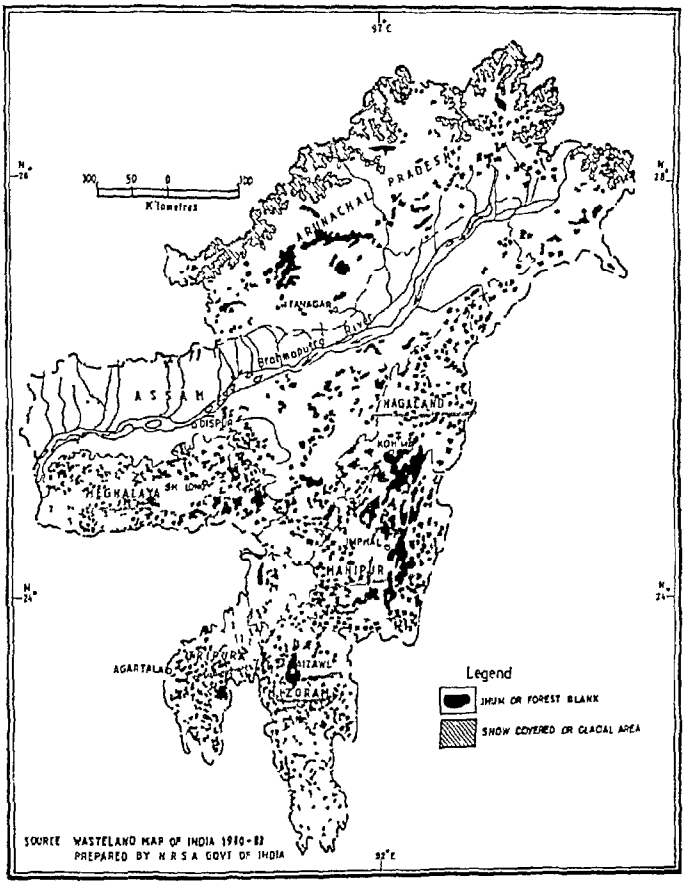


Figure 5.4
Distribution of Shifting Cultivation in South-East Asia

Figure 5.5
North-East India—Jhuming or Shifting Cultivation



In the hilly tracts of Northeast India, *jhuming* is the dominant economic activity. Over 86 per cent of the people living in hills are dependent on shifting cultivation. In 1980, about 1326 thousand hectares were under *jhuming* which increased to 1685 thousand hectares in 1990. At present (1994-95), about 1980 thousand hectares are affected by *jhuming*. The distributional pattern of shifting cultivation in Southeast Asia has been show in Figure 5.4, while Figure 5.5 shows the *jhum* or forest blank areas of Northeast India. It may be observed from Figure 5.5 that in Manipur, Mizoram, Meghalaya, Nagaland and Tripura there are vast tracts affected by *jhum* cultivation.

In the northeastern region of India, comprising the states of Assam, Manipur, Meghalaya, Nagaland, Tripura, Arunachal Pradesh and Mizoram, shifting cultivation is largely practised in the hilly areas. Almost all over the tropical world, especially in the hilly tracts of the northeastern region of India, agricultural operations in shifting cultivation are marked by the following stages:

(i) Selection of the forested hilly land
(ii) Clearing the forest tract by cutting down the jungle
(iii) Burning the dried forest wood into ashes
(iv) Worship and sacrifice
(v) Dibbling and sowing seeds
(vi) Weeding and protection of crops
(vii) Harvesting and thrashing
(viii) Merry making and feasts
(ix) Fallowing

The usual process demands the selection of a plot on or near the hill side or jungle. The selection of land is made in the months of December and January by the village elders or clan leaders. The fertility of the soil is judged by the colour and texture of the soil. In some tribes, community as a whole is collectively responsible for the clearing of the selected piece of land while in others the cutting of trees and shrubs is made by the respective family to whom the land has been allotted. At the time of allotment of land the size and workforce in the family are taken into consideration. The area allotted per family varies between half hectare to one hectare among the different

tribes, regions and states. The land is cleared of all its undergrowth and the branches of trees are lopped off. The cleared growth is allowed to dry on the field. This process of clearing which takes over a month is labour intensive, being undertaken with indigenous and primitive equipments. The dried growth as well as the trees standing in the clearance are set on fire in March. The cultivators take care that the fire should not spread into the forest. After the burning is complete, the unburnt or partly burnt rubbish are collected in one place for the complete burning. The fire kills the weeds, grasses and insects. Then, the ashes are scattered over the ground and dibbling of seeds begin in March before the advent of pre-monsoon rain.

Before sowing starts, evil spirits are worshipped and sacrifices are made for a good crop and prosperity to the family. It is believed in the interior parts of the Garo and Khasi hills that if the throat of a cock is half cut and left walking in the field and in the process it dies lying on its right, the field will bring a bumper crop and prosperity to the family and vice versa. But now sacrifice before sowing the crops is not a common practice.

On the day of sowing which is a ceremonial day for the whole village, it is interesting to observe that the male members of each family on reaching the *jhum* field in the morning engage themselves in preparing the digging sticks. The seeds are sown either by broadcast or dibbling. The dibbling and planting of seeds is an exclusive job of the female members. The male members broadcast seeds of crops like millets and small millets, whereas crops like maize, pulses, cotton, sesamum and vegetables are dibbled by females. While dibbling the seeds, the woman walk over the field with a digging stick or bill-hook in hand, make a hole in the ground, sow a few seeds and cover it over with earth by pressing it down with her toe. At the advent of rains, the seeds begin to sprout. Thus, the soil is never ploughed and no artificial irrigation is made. After sowing the crop, farmer pays cursory attention to the crop and to remove weeds from the field. The crop is, however, protected from stray cattle and wild animals by fencing the fields with bamboo. Many *Jhumias* construct a hut in the field to look after the crop properly.

Cropping Patterns in Jhuming

So far as the cropping patterns in *jhuming* are concerned, the *Jhumias*

adopt mixed cropping. The mixture of crops varies from tribe to tribe within a region. The shifting cultivators grow foodgrains, vegetables and also cash crops. In fact, the grower aims at growing in his *jhum* land everything that he needs for his family consumption. In other words, the choice of crop is consumption oriented.

Among the foodgrains the coarse varieties of rice, followed by maize, millet, job's tears and small millets are the principal crops. Cotton, ginger, linseed, rapeseeds, sesamum, pineapple and jute are the important cash crops grown in *jhum* fields. Among the vegetables, soyabean, potato, pumpkins, cucumbers, yams, tapioca, chilies, beans, onion, arum are cultivated. Tobacco and indigo are also grown. By and large, the cash crops are sold in the neighbouring markets or to the middleman who are generally *Marwaris*.

In the mixed cropping, soil exhausting crops, e.g , rice, maize, millets, cotton, etc., and soil enriching crops, e.g., legumes, are grown together. This practice has many direct and indirect advantages. These crops harvest at different periods, thereby providing the tribes with varied food for nearly six to nine months in a year. The same *jhum* land is cropped by the community for two or three years, thereafter, the land is abandoned to recuperate. Occasionally, some residual crops are collected from the abandoned fields.

Jhum Cycle

The *jhum* cycle is influenced by the pressure of population, nature and density of forests, terrain, angle of slope, texture of soil and the average annual rainfall. Areas of sparse population generally have longer *jhum* cycle (15-25 years), while areas with high density of population have shorter *jhum* cycle (5-10 years).

The patches of land for shifting cultivation are not selected in any given order or sequence. There is always a room for choice. The period of consecutive cropping and fallowing differs from region to region and from tribe to tribe. We do not know after what length of time the primitive inventor of shifting cultivation had to come back to the same plot because he had vast areas to move about. But our present generation, with the increase in population and being somewhat staked down to smaller areas, a shifting cultivator has not got much choice left to shift about. His world has become small, he has

to be content moving about in narrow circles and the circle is becoming increasingly smaller with the passage of time. In brief, in the earlier decades, the period before which the *Jhumias* returned to cultivate the same plot was quite long. This was partly due to the limited population and partly to the better fertility of soil which used to be rested for nearly thirty to forty years.

Table 5.1

Northeast India : Jhum Cycle, Period of Occupancy and Duration of Fallowing

Tribe	*Average annual rainfall (in cms)*	*Duration of cropping*	*Fallowing period*
Ao (Mokokchung Dist)	150 cm	one year	5-8 years
Garo (Garo Hills)	125 cm	one year	5-10 years
Hmars (W Manipur)	130 cm	one year	5-10 years
Idu-Mismi (Lohit)	250 cm	two years	5-10 years
Jaintia (Maghalaya)	250 cm	one year	4-8 years
Khashi (Maghalaya)	300 cm	one year	4-6 years
Konyak (Nagaland)	140 cm	one year	5-10 years
Lakhar (S Mizoram)	125 cm	one year	6-12 years
Lotha (Nagaland)	145 cm	two years	10-15 years
Lushai (Mizoram)	185 cm	two years	8-15 years
Mikir (Mikir Hills)	150 cm	one year	5-7 years
Pawi (S C. Mizoram)	210 cm	one year	8-10 years
Rengma (Nagaland)	150 cm	tow years	7-15 years
Sema (Nagaland)	155 cm	two years	6-10 years
Sherdukpen (Kamang)	125 cm	two years	6-10 years

The period of consecutive cropping also varies from tribe to tribe. In Arunachal Pradesh, for example, a clearing is generally cultivated for two years. As one patch every year is abandoned, a new patch is cleared. Thus, two patches are cultivated simultaneously every year, and these two patches are generally quite at a distance from each other. This involves long arduous journey to and from the field.

The *jhum* cycle, the period of occupancy and duration of fallowing of some of the tribes of the hilly tracts of northeast India have been given in Table 5.1. An examination of data shows that excepting Idu-Mismi (Lohit district), Lotha, Rengma, Sema (Nagas),

Lushai (Mizoram) and Sherdukpen (Kemang) most of the tribes of the region occupy *jhum* land for sowing only for one year. The main cause of abandoning the fields is the rapid depletion of soil. The fallowing period is less than fifteen years. In the territories of Aos, Khasis, Mikirs, Jaintias, Garos, Semas and Hmars, it is less than eight years. The tribes in which the *jhum* cycle is around five years are facing serious problems of undernourishment and their ecosystems are fast losing their resilience characteristics.

Rotation of Crops

Information about the rotation of crops adopted by the *Jhumias* of the northeastern region of India was collected during fieldwork in 1978-84. Some of the important rotations have been presented below in Tables 5.2 to 5.8.

Table 5.2

Arunachal Pradesh · Rotation of Crops

	First Year		*Second Year*	
	Kharif (summer crops)	*Rabi (winter crops)*	*Kharif (summer crops)*	*Rabi (winter crops)*
(i)	Maize, arum, yam, millets, ginger, tobacco, potato, vegetables	—	Paddy	Short duration paddy or small millets
(ii)	Papayas, paddy, maize, millets, beans	—	Paddy	Millets and vegetables

Table 5.3

Assam · Rotation of Crops

	First Year		*Second Year*	
	Kharif	*Rabi*	*Kharif*	*Rabi*
(i)	Rice, maize, millets, arums, tapioca, cucumber, ginger, sorrel, *mejak*, castor, tobacco, bean	—	Small millets mixed with short duration paddy and vegtables	—
(ii)	Millets, maize, tapioca, beans, brinjal	—	Paddy and vegetables	—

Table 5.4

Garo Hills (Meghalaya) Rotation of Crops

	First Year		*Second Year*	
	Kharif	*Rabi*	*Kharif*	*Rabi*
(i)	Millets, maize, cotton, sweet potatoes, vegetables pegion pea	—	Short duration paddy, tobalchu, tapioca, lac	—
(ii)	Paddy, maize, millets, seamum, yam, hilly cucumber, brinjal, pegion-pea	—	Small millets, pegion pea. vegetables	—

Table 5.4a

Khasi Hills (Meghalaya) Rotation of Crops

	First Year		*Second Year*	
	Kharif	*Rabi*	*Kharif*	*Rabi*
(i)	Maize, rice, millets, *kri* (small millets) sweet potatoes, pumpkins cucumber, ginger, tapioca, beans	—	Short duration paddv or millets or both mixed	—
(ii)	Maize, beans	Potato	Maize, mixed paddy vegetables	Potato
(iii)	Potato	Cabbage	Potato	Potato

Table 5.5

Manipur Rotation of Crops

	First Year		*Second Year*	
	Kharif	*Rabi*	*Kharif*	*Rabi*
(i)	Paddy, maize, millets, arums, linseed, *chakwai* (pulse), ginger	—	Short duration paddy and vegetables	—
(ii)	Millets, maize, cotton beans, pumpkins, sweet potatoes, squash, *nunghwai* (pulse)	—	Millets and vegetables	—
(iii)	Paddy, mustard, arum, sesamum	—	Small millets and vegetables	—
(iv)	Maize, millets, sesamum, chilly pumpkin, cotton sweet potatoes, pulses, beans, mustard, groundnut	—	Vegetables, pulses, millets, chilly	—

Table 5.6

Nagaland (Sema Tribe) Rotation of Crops

	First Year		*Second Year*	
	Kharif	*Rabi*	*Kharif*	*Rabi*
(i)	Paddy, soyabean, kachu, maize, sesamum, vegetables	—	Short duration paddy or maize or small millets	—
(ii)	Paddy mixed *nagdal* or maize mixed nagdal	—	Small millets	—
(iii)	Lobster, maize *nagdal*	—	Small millets mixed *nagdal*	—
(iv)	Potato	—	Potatoes or early paddy or millets	—

Table 5.7

Nagaland (Ao and Angami Tribes) Rotation of Crops

	First Year		*Second Year*	
	Kharif	*Rabi*	*Kharif*	*Rabi*
(i)	Paddy, mixed maize, kachu chillies, sesamum, paddy and vegetables	—	Short duration paddy or small millets	—
(ii)	Paddy mixed *nagdal*, chillies, vegetables and sesamum	—	Paddy or millets	—
(iii)	Maize mixed paddy vegetables and sesamum	—	Paddy	—
(iv)	Maize mixed small millets, ginger and vegetables	—	Paddy	—
(v)	Potato	—	Potato	—

Table 5.8

Tripura Rotation of Crops

	First Year		*Second Year*	
	Kharif	*Rabi*	*Kharif*	*Rabi*
(i)	Millets maize, vegetables cotton, sesamum, pegion pea ginger	—	Maize paddy, jute, vegetables, ginger	—
(ii)	Paddy, vegetables, cotton	—	Millets, maize vegetables	—
(iii)	Maize, millets, jute, vegetables	—	Small millets, vegetables	—

Thus, it is evident from the above that in all the rotations a mixture of a several crops is sown in the *kharif* season of the first year. In the *kharif* season of the subsequent year some short duration cereals of inferior quality are sown mixed with beans and other vegetables.

Intensity of Cropping

Over 5 lakh tribal families are dependent on shifting cultivation in the Northeastern region of India. The region has the largest area under *jhum* cultivation in the country. Out of the total reporting area of 33 million hectares, about 3 million hectares are under cultivation and out of this 2.6 million hectares are under *jhum* cultivation.

Table 5.9 depicts that the area available for cultivation is not cultivated at the same point of time. Only about 16 to 25 per cent of the *jhum* land is cultivated annually. The proportion of the area varies in different states and within each state also, depending on the size of population in a particular tract. Nagaland and Mizoram have the largest area under shifting cultivation, i.e., 6.08 and 6.04 lakh hectares respectively, while Manipur has the least area, i.e., about one lakh hectares under *jhuming*.

Table 5.9

Cultivated Land in Northeastern Region of India

(in lakh hectares)

State/Union Territory	*Reporting area*	*Net area sown*	*Area available for jhuming*
Arunachal Pradesh	57 93	0 70	2 48
Assam	78 81	21 98	4 98
Manipur	22 11	0.79	1 00
Meghalaya	27.79	1 58	4 16
Mizoram	16 54	0 61	6 04
Nagaland	13 51	0 47	6 08
Tripura	10 66	2.36	2.21
Total	227.35	29 49	26 95

Source · Data published by the N-E Council

The tenurial pattern of land, whether owned by a clan, community or individual, also influences the cropping patterns. Where the land belongs to a community or clan, there appears to be little interest

on the part of individual tribal family to improve the fertility of soil. In the northeastern hilly region, the *jhum* land belongs to the community and, therefore, it is difficult to check the practice of *jhum* cultivation or to increase the fertility of land.

An examination of Table 5.10 reveals that Manipur has the lowest area under *jhuming* in northeast India. At one point of time, it, however, has the maximum area under *jhum* crops. Manipur and Tripura have only about 10 per cent of their *jhuming* land under crops in agricultural year.

Table 5.10

Situation of Shifting Cultivation in Northeast Region of India

(in thousand hectares)

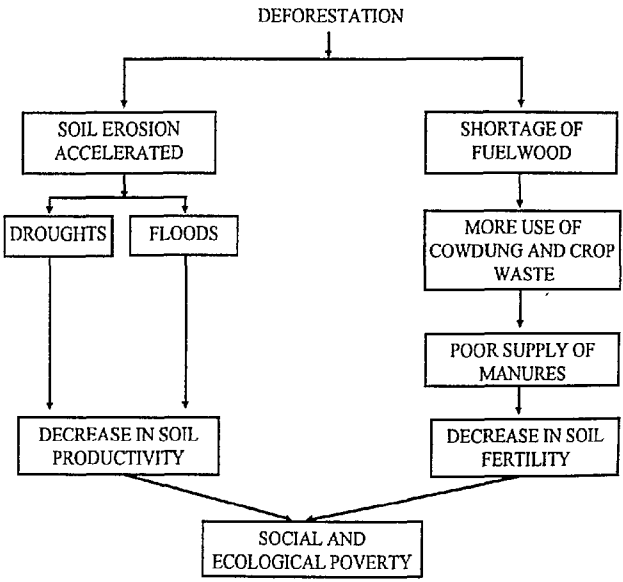
State/Union Territories	*Area affected by jhum*	*Area under jhum at one point of time*	*Number of tribal families involved (in thousands)*
Arunachal Pradesh	248	92	148
Mikir Hills (Assam)	415	54	45
North Cachar Hills (Assam)	83	15	13
Manipur	100	60	50
Meghalaya	416	76	69
Mizoram	604	61	45
Nagaland	608	73	80
Tripura	220	22	43
Total	2694	453	492

Source Report of National Commission on Agriculture, Part IX on Forestry, 1976

Shifting Cultivation: Problems and Prospects

Clearing of jungles is the prerequisite of shifting. The felling of trees and clearing of bushes, however, accelerate soil erosion and accentuates variability of rainfall which may lead either to droughts or floods. The overall impact is the decline in soil fertility. The ecosystems lose their resilience characteristics. The population dependent on shifting cultivation faces the shortage of food, fuelwood and fodder. Consequently, the nutritional standard goes down. These processes culminate into the social poverty and ecological imbalance (Fig. 5.6).

Figure 5.6
Deforestation and Soil Depletion



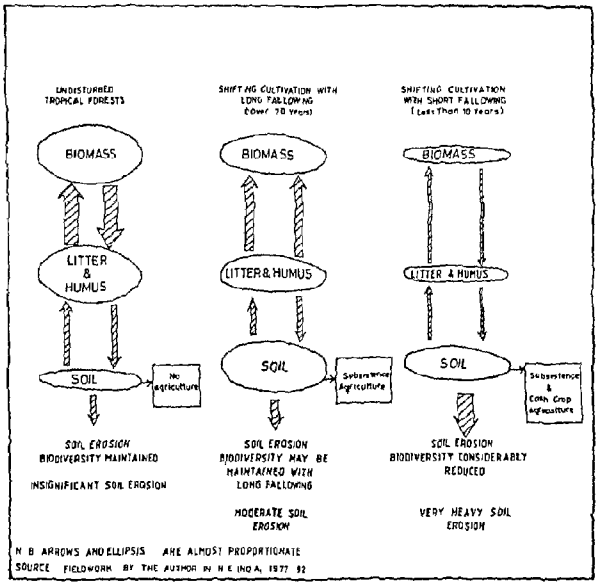
DEFORESTATION AND SOIL DEPLETION

Source Based on the field observations

The impact of shifting cultivation on biomass and soil erosion has also been shown in Figure 5.7. From there it may be observed that as the cycle of shifting cultivation becomes shorter, the biomass on which depends the humus of soil declines and the biodiversity is considerably reduced. The subsistence agriculture disappears and the relatively strong cultivators start acquiring community land. They also start engaging lobourers which goes against the gamut of their society and mode of life.

The transformation of natural vegatation as a consequence of shifting cultivation has been shown in Figure 5.8. It may be observed from this figure that in the Siang district of Arunachal Pradesh good tracts of Oak forest have been transformed into pines, scrubs and grasses, while in Shillong (Meghalaya) and Cachar Hills (Assam)

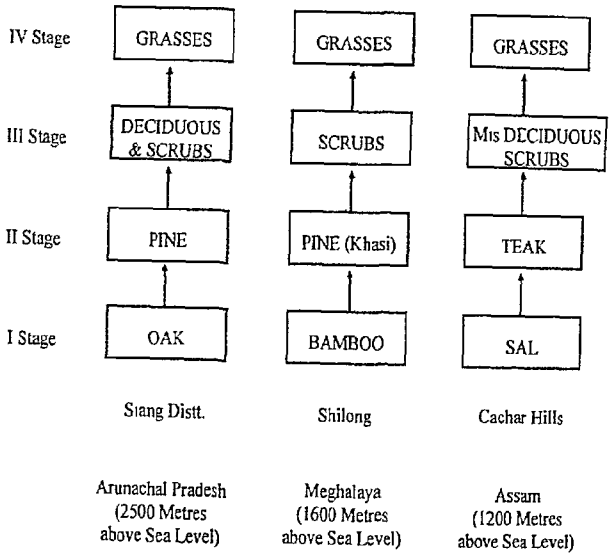
Figure 5.7
Shifting Cultivation, Biomass and Soil Erosion



bamboo and Sal (teak) forest have been transformed into deciduous scrubs and grasses Thus shifting cultivation is gredly reducing the forest wealth and damaging the ecology beyond redamption in Northeast India (Fig. 5.8).

There are divergent opinions about the evil and adverse effects of shifting cultivation on the ecology and environment of the region Many of them hold the view that it is primitive and depletes the forest, water and soil resources Since *jhumung* damages the ecosystems, it should be stopped completely. According to the opposite views, supporting the continuance of shifting cultivation with necessary and effective reforms, it does little damage to soil erosion as the high hu-

Figure 5.8
Shifting Cultivation and Transformation of Natural Vegetation



midity and heavy rainfall in the region do not permit the soil to remain uncovered for long. Some form of vegetation immediately covers the top soil which checks the soil erosion. During the agricultural operations also, as no ploughing, hoeing and pulverization of soil is done, the soil remains compact. Moreover, *jhuming* lands are generally steep slopes on which sedentary cultivation cannot be developed easily. In fact, *jhuming* is a way of life, evolved as a reflex to the physiographical character of land under special ecosystems. It is practised for livelihood and not without the knowledge of its adverse effects.

Assessing the fact that *jhuming* system cannot be stopped altogether, it is necessary to make the process more productive so that it may sustain the growing pressure of *Jhumias* population at a reasonably good standard of nutrition. For a change in *jhuming* typology it is essential that the *Jhumia* is provided with land where he can culti-

vate and derive profits permanently. Once the retrainability of soil is ensured, then the question of augmenting the soil fertility through the addition of manures and fertilizers could be meaningful. Measures should be taken to see that *Jhumias* are trained in other types of occupations. They should be given training in raising trees, orchards and plant protection, cottage and small industries, and indigenous handicrafts. Moreover, they should be trained in the development of dairying, piggery, sheep-rearing, poultry, duck-keeping, fisheries, bee-keeping, agriculture, etc. For the effective implementation of these programmers, extension service, cooperative and marketing facilities are essential. The establishment of forest based small industries may also help in boosting up the economy of the tribes

New crops of economic importance have to be developed and their diffusion should be extended in the isolated hilly areas. In fact, a cropping pattern with higher inputs (the inputs be provided at the subsidized rates by the government) will enable greater yields to be obtained per unit area and that will help in detracting the *Jhumias* from the uncertain way of life of shifting cultivation.

The main approach to overcome the evil of shifting cultivation should be to change the *jhuming* lands into sedentary farms. In the hilly areas, one of the most common measures that has been adopted in may small tracts with success is the construction and development of terraces. Different types of terraces can be adopted to fit in with a particular type of ecosystem. These terraces have a definite advantage towards achieving sedentary farming in the areas of shifting cultivation. It has been accepted by most of the planners that terracing has to play a major role if agricultural land use in the hilly tracts is to be made more efficient.

There are, however, many technoeconomic problems in the development of terraces. Terracing, apart from being a costly measure, requires adequate irrigation facilities which in the mountainous areas cannot be provided easily. It, therefore, may not be feasible to go for large scale terracing. The human energy input used in the *jhuming*, however, can be used for the development of small terraced farms. In several tracts on the northeastern hill region, terraces have been developed with the help of local human energy input involving very little direct monetary input. Small demonstration centers in various

pockets, providing technical helps, development of road connections and taking the farm community leaders on field visits to terrace cultivation area may probably help in avoiding huge capital expenditure for large scale terracing. This would provide productive use of human energy for land resource development.

So far as the scope limit for the development of terraces is concerned, it is difficult to prescribe any slope limit, unless detailed evaluation of existing terrains in the region is made and other technical details are experimentally studied. A slope of 20 degree can be terraced and in the steep slope areas partial terracing can be done. Once soil is properly developed with the help of manures and crop rotation practices the shifting typology will gradually get transformed into sedentary system.

Apart from terracing, other soil conservation measures like bunding, trenching, gully plugging, etc., can be adopted according to the need of the area. Equally important is the development of protective covers, like forests or fruit trees, suitable cash crops, grasses and leguminous crops especially on steep slopes. In short, land use planning and practices should be based according to land capability and suitability.

The shifting cultivation is a way of life and there are cogent reasons behind the customs and practices of the tribal people. The climate, the terrain, their food habits, their needs, their self-reliance—all have a say on shifting cultivation. The whole gamut of primitive society is interwoven with the means of food production. In other words, their way of life, training of youths, social and political systems, the ceremonies and festivals and, in brief, their philosophy of life is the product of *jhuming* system of economy. This is why many of the new methods of cultivation, recently introduced in the tribal areas, are yet to generate the process of cultural acceptability. Transformation of *jhuming* cultivation into sedentary farming, therefore, should be gradual and evolutionary. The radical and revolutionary approach for the transformation of *jhum* system may not be acceptable to the people of the tradition bound society of the tribals.

Shifting cultivation is one of the greatest threats to the biodiversity of our planet, destroying about 10 million hectares of tropical forests annually. Nevertheless, it supplies farming families with

food, firewood, medicines and other domestic needs, though it produces low yields of crops and has almost no potential beyond subsistence farming. Moreover, where population densities are low and forest areas vast, slash and burn practices are sustainable and harmonious with the environment The long term objective should be to develop alternatives to shifting cultivation that are ecologically sound, economically feasible, and culturally acceptable.

The environmental degradation as a result of shifting cultivation may be checked substantially by:

(i) developing practical and relevant guidelines for policies that encourage farmers to adopt technologies that are ecofriendly and environmentally sound;
(ii) improve conditions for people living near the forests by diversifying land use and thereby increasing food production;
(iii) protect biodiversity and ensure better use of genetic resources;
(iv) increase soil productivity and reduce emission of greenhouse gases by capturing carbon in the soil. Intensification and modification of traditional systems—prolonged cropping cycles and decreased fallow periods—will lead to increased soil organic matter and plant biomass;
(v) involve local people at all stages of decision making as well as in all research processes;
(vi) amalgamate the most indigenous knowledge, and national and international experience and expertise;
(vii) develop suitable strategies for agricultural marketing and subsidies;
(viii) design biological barriers to prevent soil erosion and water runoff;
(ix) develop tree, crop and pasture systems that cycle nutrients and enhance soil fertility, reducing the need for expensive inorganic fertilizers; and
(x) evaluate policy option for reclamation of degraded lands

All these steps, if taken together, may go a long way in improving the socioeconomic conditions of the shifting cultivators as well

as enhance the sustainability of the ecology and environment.

Sedentary Agriculture

Agriculture as practised in one place by a settled farmer in which fields are not rotated is called sedentary agriculture. The term was used for primitive agriculturists in tropical Africa who farmed the same piece of land indefinitely in contrast to shifting cultivation

Sedentary agriculture is mostly confined to the tropical lands where the fallowed fields are frequently reused and the cultivator stays permanently at one spot. The rotation of crops is practised and in comparison to shifting cultivation, greater attention is paid to the land and to the crop sown. The methods of tillage are intensive; ploughing and hoeing of the soil is done with crude, hand implements. There is more employment of manpower in the fields. Mixed cropping is adopted and more than one crops in a year are sown. The intensification of agriculture helps in sustaining a relatively larger population on a permanent basis at a better standard of subsistence and nutrition. The farmer keeps many more cattle including cows and buffaloes. The domesticated animals are used for draught purposes as well as for milk and meat purposes. The crops are generally sown in the cool season which grow throughout the rainy period and are harvested in the dry season. The crops, like maize, millets, paddy, vegetables, sweet-potatoes, root-crops, banana, tapioca, squash, tobacco, small millets and pulses are grown in this type of agricultural system.

Many sedentary farmers in South America and southeast Asia in the off season find some job in plantation and return to their homes periodically with their earnings. In southeast Asia and west Africa subsistence sedentary farming is often combined with the cultivation of cash crops or with the collection and sale of forest products.

Intensive Subsistence Agriculture

Subsistence agriculture is the type of farming in which crops grown are consumed by the grower and his family Subsistence agriculture may be of different types. It may be shifting or settled agriculture, it may be primitive or non-primitive in character, it may be both intensive and extensive in nature. As long as its major purpose of fulfilling needs of its producers it remains subsistence farming.

The main distinction between primitive (shifting) and non-primi-

tive (sedentary type of subsistence agriculture) depends on the tools and equipments used. The tools of the primitive agriculturists are more or less the same as those used in shifting cultivation, while in non-primitive subsistence agriculture wooden plough, harrows, hedges and permanent bundings are used. In India subsistence agriculture is practised in the areas of isolation and relative isolation in Bihar, Orissa, Madhya Pradesh, Rajasthan, Northeast India, Bundelkhand and the Western Ghats.

The intensity of agriculture and multiple cropping are directly governed by the pressure of population in a given region at a given point of time. In shifting cultivation tracts where the density of population per square kilometre is generally less than ten persons, the intensity of agriculture is very low. The land is such areas is sown only once in a year and that too abandoned after on over two years. But in those parts where density of population is relatively high, at least two crops in a year is the usual practice and the same piece of land is sown season after season and generation after generation.

Intensive subsistence agriculture is best developed and practically confined to the monsoon lands of Asia. It is carried on mainly in China, Japan, India, Bangladesh, Myanmar (Burma), Thailand, Sri Lanka, Malaysia, Philippines, Indonesia, Laos, Cambodia and the islands of Pacific Ocean, Indian Ocean and southeast Asia These are the most densely populated parts sustaining about two-third population of the world. In these countries, the density of population is higher than that of the industrial countries of Europe and America. The fast growing population, almost unchecked for centuries, necessitates an even greater intensity in the tillage of land. Farming in both the wet lowlands and the terraced uplands is, therefore, very intensive to support the dense population of teeming million. There are two types of the intensive subsistence agriculture. One is dominated by wet paddy and the other is dominated by crops other than paddy, e.g., wheat, pulses, maize, millets, sorghum, kaoling, soyabeans, tubers and vegetables.

Intensive Subsistence Agriculture Dominated by Wet Paddy

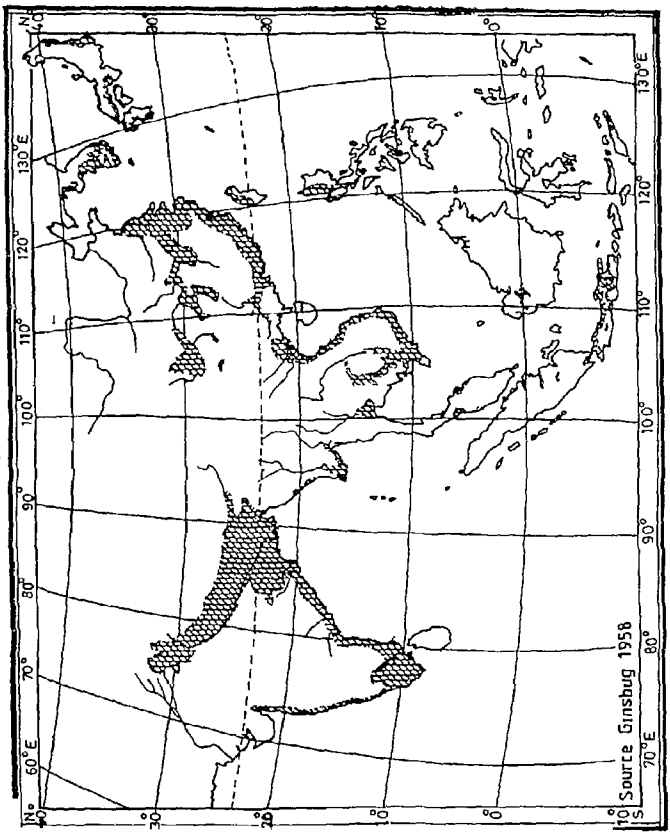
Intensive subsistence agriculture dominated by wet paddy is practised mostly in the Monsoon Asia. In this agricultural typology, the size of holding is generally very small. Farm sizes are also very small

and they, through many generations, have been subdivided so that they have become extremely small and often uneconomic to run. An average farm in Japan is 0.6 hectare, and in some parts of Kerala and West Bengal it is even smaller. Individual peasants grow crops mainly to support their families, though there may be some surplus for sale which fetches some amount for the farmers secondary and tertiary needs. In the Monsoon Asia the farmers are so 'land hungry' that almost every bit of tillable land is utilized for agriculture. The fields are separated only by narrow handmade ridges and footpaths by which the farmers move around their fields. The boundary bunds, locally called as *maindh* or *daul*, are kept very narrow to save space. Only the steepest hills and the infertile and alkaline (*reh* and *kaller*) patches of land are left uncultivated. The farming is so intensive that two and even three crops of rice can be raised in one year. In tracts where only one crop of rice can be raised the fields are normally used in the dry season to raise other food or cash crops such as oats, pulses, tobacco, oilseeds and vegetables.

In wet paddy agriculture, traditionally much manual and hand labour is required. Ploughing is done with the help of buffaloes, oxen, mules and horses. Paddy crop is planted in narrow rows by females, while hoeing and harvesting operations are done by both males and females. Harvesting and thrashing are done manually. The farm implements are often very simple. Machines have been developed recently which can work on the flooded plains for ploughing and hoeing. Small machines are used in the farms of China, South Korea and Japan which are gradually being diffused in other countries of Monsoon Asia.

In this type of agriculture the cultivator concentrates on the cultivation of food crops, especially rice and vegetables, Comparatively, few sheep, goats or horses are kept in wet paddy areas. He-buffaloes are kept as draught animals in many parts of the monsoon world. Poultry on a small scale is common and pigs are kept as scavenger animals on the Chinese and Japanese farms. Many farmers practise fish culture in paddy fields. Fish culture in paddy fields is carried on in Assam, Arunachal Pradesh, West Bengal (India) and Bangladesh with the set objective to satisfy the protein demand of the farmer's family. In paddy intensive subsistence farming the farmers make use

Figure 5.9
The Distribution of Wet Rice Cultivation in Asia



of every available type of manure, including farm waste, rotten vegetables, fish waste, cowdung and human excreta to ensure higher agricultural returns and also to maintain the high fertility of the land. The green manuring and chemical fertilizers are also used to enhance the productivity of land. In India, the farmers of West Bengal, Kerala, the coastal Andhra Pradesh and Tamil Nadu provide a good example of intensive subsistence wet paddy agriculture (Fig. 5.9).

Intensive Subsistence Agriculture Dominated by Other Crops

Owing to variations in terrain, soil, vegetation, temperature, length of growing season, moisture conditions, sunlight, wind and many socio-economic constraints, it is neither practicable nor profitable to grow paddy in many parts of the monsoon world. In the intensive subsistence farming, dominated by other crops, the methods and operations of cultivation are equally intensive and farming is on subsistence basis. In north China, Manchuria, North Korea, and Punjab, Haryana and western Uttar Pradesh in India, wheat, maize, millets. pulses. soyabean and oilseeds are intensively grown. In Myanmar, Thailand and peninsular India, millets, maize and pulses are the dominating cereal crops as soil moisture in these area is not conducive for the cultivation of paddy. Farming in these regions has very similar features to those of wet paddy cultivation. There is intensive use of land, multiple cropping, heavy use of manual labour, little use of farm machinery and use of a variety of manures and fertilizers.

In India, operational holdings and sizes of fields are generally small and uneconomic. About 25 per cent of the total rural population has land less than 0.4 hectare and another 25 per cent is landless. As a result, the farmers are poor and the majority of them cannot afford to purchase modern agriculture implements, fertilizers, quality seeds, insecticides and pesticides. Though tractors are popular in the relatively large farms of Punjab, Haryana and western Uttar Pradesh, yet the oxen and buffaloes are the principal draught animals. Most of the agricultural operation are, however, labour intensive

Intensive Agriculture

The application of more labour and capital to relatively small unit of land, in order to obtain higher yields and to produce several crops from the some field in a year, is called intensive cultivation. In inten-

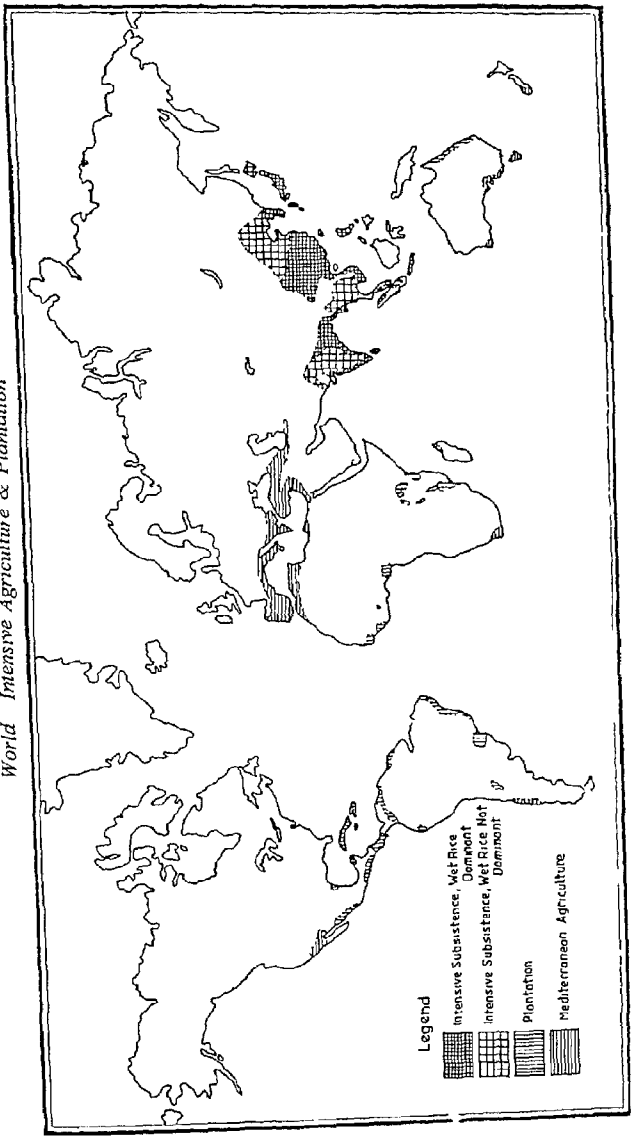


Figure 5.10
World Intensive Agriculture & Plantation

sive cultivation heavy dozes of fertilizers, better quality of seeds, insecticides, irrigation, crop rotation and green manuring practices are adopted. This type of agricultural typology is found mainly in those parts of the world where the pressure of population on agricultural land is high and the per capita share in cultivated land is low The countries like China, Japan, Bangladesh, India, Sri Lanka, Indonesia, Malaysia, Philippines, Vietnam, Thailand, Laos and Combodia practise intensive agriculture (Fig. 5.10).

Intensive agriculture can be classified into: (i) intensive agriculture dominated by wet paddy, and (ii) intensive agriculture dominated by other food crops. A description of these agricultural topologies have already been given under the heading of intensive subsistence farming. The salient characteristics of intensive agriculture are: (i) very small holding, (ii) small size of fields, (iii) much manual labour is entailed, (iv) cattle farming is less developed, (v) multiple cropping, (vi) application of diverse manures and fertilizers, and (vii) application of irrigation water if available.

Extensive Agriculture

Extensive agriculture is relatively a new development. It is carried on in the continental lands of the mid-latitudes where nomadic herdsman roamed previously. The continental areas, well away from maritime influence and the low precipitation between 300-600 mm, make crop cultivation a calculated risk. It was farm machinery which enabled farmers to cultivate grains like wheat on a large scale in these areas The linkage of extensive areas with the outside world is mainly by railway and bulk of grain harvest is exported. The extensive farming is best developed in the eastern steppes of Russia, Ukraine, Kazakistan and Uzbaikistan, the central and western plains of the United States, the Canadian 'prairies', the 'pampas' of Argentina and the Australian 'down'. This is highly mechanized farming on large holdings, employing little labour, with relatively low yields per hectare and a large total yield. The per man production in extensive cultivation is fairly high. It is practised in the sparsely populated areas where new lands found be bought under cultivation.

In extensive agriculture the size of farm is generally large, ranging from 240 to 16000 hectares; settlements are small and often widely scattered leading to isolation as a major problem. The cultiva-

tion is highly mechanized and thus all agricultural operations, starting from ploughing to hoeing, harvesting and thrashing, are done entirely with the help of machines The tractors, plough, drills, combine harvestors, thrashers and winnowers are the large agricultural machines used in extensive farming Large barns are erected by the farmer for the storage of cereals

Monoculture of wheat is the main characteristic of extensive agriculture The farmers grow either winter wheat or spring wheat, depending on the time and season of sowing of the crop Among the other cereals, barley, oats, rye, flax and oilseeds are grown The wheat grown on extensive mechanized farms gives a comparatively low yield and the average is seldom more that 1500 kg per hectare, whereas under intensive cultivation in Japan and Punjab the yield per hectare is more than three times In extensive cultivation the labour force is small but due to mechanization agriculture per man production is high Other features of extensive agriculture are lack of irrigation, ownership of farm lying with the farmer and the absence of the tenant system At the peak of harvesting period a few extra hands may be hired The crops are prone to climate hazards The fluctuation in the market leads to loss to the grower and, therefore, they have started more mixed farming in place of monoculture of wheat

The major belts of wheat production have, however, constantly been shifted away from the major market areas, a consequence of rising land values, as population has grown and expanded outward from eastern USA, Buenos Aires, coastal Australia and Ukraine The movement has been into more arid regions The extensive farming has been displaced by more intensive mixed farming systems, and has in turn invaded areas occupied by even more extensive system, e g, ranching and nomadic herding The stereotype of the large mechanized wheat monocultural farm system was thus started in the ninteenth century This agricultural typology now survives in just a few areas in the world and is under rapid transformation stage leading towards mixed and intensive commercial farming

Plantation Agriculture

The term 'plantation agriculture' was originally applied specifically to the Brithish settlements in America and then to any large estate in North America, West Indies and Southeast Asia which was culti-

vated mainly by Negro or other coloured labour, living on the estate under the control of the proprietors or managers. It represents the development of agricultural resources of tropical countries in accordance with the methods of secondary occupations or western industrialism. It is a large scale enterprise in agriculture. Plantation involves the existence of a regular force under the control of a more or less elaborate management and frequently a considerable capital outlay, although some of the plantation crops, except tea and rubber are also grown in small holdings.

The plantation agriculture is practised mainly in the tropical areas to grow cash crops. It is a specialized commercial cultivation of cash crops on estates or plantations. Some of the important plantation crops are rubber, oil-palm, cotton and copra. beverages like tea, coffee and cocoa, fruits like pineapple, banana, sugarcane, hemp and jute. The farming in plantation is executed with specialized skill and, wherever, possible with the application of machinery, fertilizers, weedicides, insecticides and pesticides. It aims at high yields, high quality production and a large output, most of which is exported The final products, whether sheet rubber, palm-oil or tea, have to be carefully processed and standardized to meet the world demand and specifications. The competition in such production is very keen. Large estates are, therefore, better able to meet these demands than individual, small holders and farmers.

In the tropics and subtropics where plantation agriculture is practised, the use of white labour was known impossible during the eighteenth and ninteenth centuries for climatic and health reasons. All parts of the tropical climate are, however, not equally well suited to the development of plantation agriculture. Some areas have very heavy and continuous rainfall, others have very little precipitation. The excessive amount of water in the soil alters various chemical and biological processes, limiting the amount of oxygen and increasing the formation compounds that are toxic to plant roots. On the other hand, drought and scanty rainfall results into withering of crops if moisture to the crop is not supplied artificially. Again, temperature conditions are not always adapted to the growing of the desired products nor are they favourable for man. Further, climatic hazards, strong winds, topography, drainage, soil, vegetation conditions often

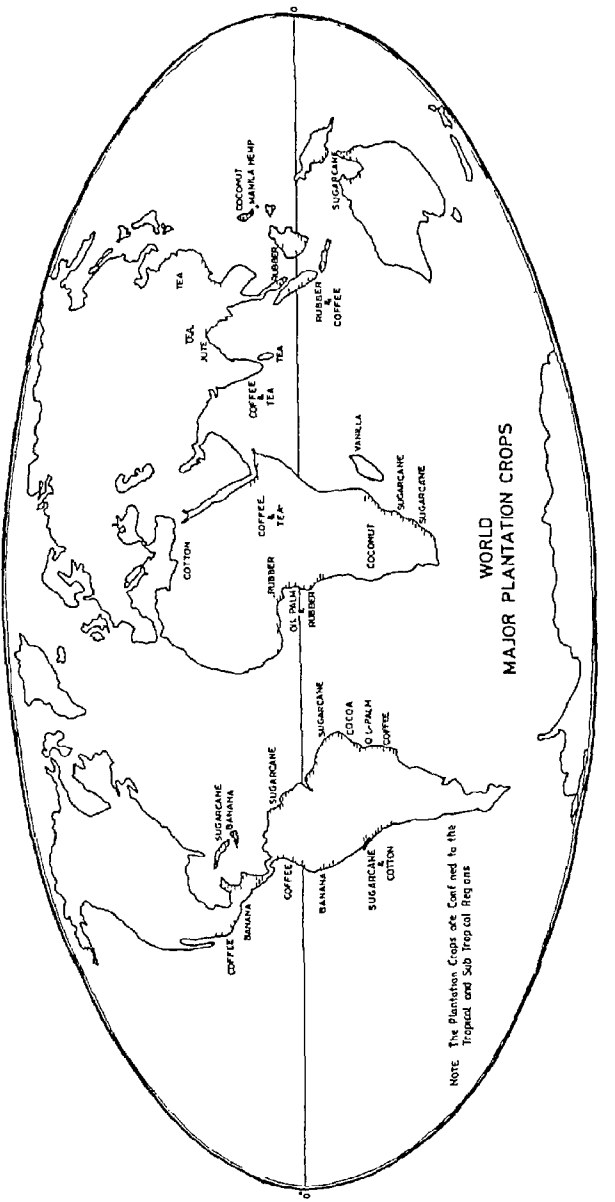


Figure 5.11
World Major Plantation Crops

handicap or may even prevent the development and establishment of plantation estates. Accessibility and connectivity, availability of labour, difficulties of clearing vegetation, prevalence of disease and insects, pests, weeds, rapid deterioration of the tropical soil and soil erosion are some of the main problems of plantation agriculture. Owing to these physico-socioeconomic constraints plantations agriculture is confined in relatively narrow areas of the tropics along the sea coasts and in those tracts which are well served by roads, railways and navigable rivers.

The plantation farms are generally large and are found mainly in the thinly populated areas. The size of farm varies from 40 hectares in Malaya and India to 60000 hectares in Liberia. In these estates a large disciplined but unskilled labour force is necessary. Because plantations have usually been established in the sparsely populated areas, labour has to be imported and provided with housing, food, education, postal and medical facilities. In the past slavery was a solution of the problem, and later indentured labourers, particularly Indians, went to sugarcane plantations in various parts of the British Empire. Indians also provided much of the labour to the rubber estates of Malaysia, tea gardens of Sri Lanka and the sugarcane farms of West Indies.

The technical and managerial staff has invariably been European on the plantations. Nearly all the plantation crops have to be processed before leaving the estate. There are a number of reasons for this processing. First, the yield of many crops decline quickly after harvesting; secondly, the processing gives a product of a higher value per unit weight that can be transported over long distances; and thirdly, many crops are perishable in their unprocessed forms. The need for processing plantation crops differs from crop to crop but as a matter of fact the more complex the process the more likely the crop is to be produced on plantations rather than on small holdings. The annual crops are less suited for plantation than perennial trees, plants or bush crops. The perennial crops like rubber, tea and coffee need far less cultivation, they give yields for several years and do not have marked seasonal labour peaks. Plantation system, on the whole, however, largely depends on the exploitation of cheap labour.

The continentwise analysis reveals that Asia is the leading pro-

ducer of jute (96 per cent), rubber (90 per cent), tea (87 per cent), coconut (77 per cent), groundnut (53 per cent), cotton (37 per cent) and tobacco (46 per cent) of the total world production Asia's share in the production of sugarcane is 39 per cent and that of banana and oil-palm is 25 per cent each (Fig 5 11)

Africa leads in the production of cocoa (72 per cent), oil-palm (69 per cent) and sisal and agaves (49 per cent) Other significant plantation crops of Africa are groundnut, coffee, cotton, rubber, tea, sugarcane, coconut and tobacco In the Oceania coconut and sugarcane are the only plantation crops sharing only 6 per cent and 4 per cent respectively of the percentage of weight of output in the world

Mediterranean Agricultural System

This agricultural typology is confined to the coastal areas of the Mediterranean Sea in Europe, Asia Minor and North African coastal strips (Fig 5 10) Outside the Mediterranean coast, this system is found in California (USA), central Chile, the southwest of Cape Province (South Africa), and southwest of Western Australia The main characteristics of the Mediterranean climate are that winters are mild and wet and summers are hot and dry

The agricultural landscape of Mediterranean regions has been largely affected by the long dry summers, occurrence of rains during the winter season and devices for artificial irrigation during the drought periods of summers From the classical period the land was planted with figs, vine, laden trees, usually elm, poplars and ash (*arbusta*), and olive groves Cereals were subordinated to the tree crops in the Mediterranean lands, especially in Italy, Sicily, Morocco and Asia Minor On the highly fertile lands, vines were grown in the ancient times at a density of 3200 plants to the *jugerum* (the area that a man and two oxen could plough) The small fields in irrigated parts were devoted to corn, figs, and olives In the agricultural landscape of Mediterranean, vine and citrus fruits still occupy a significant position A typical village community grows wheat and barley in the plain, and graze sheep and goats on the stubble, it grows olives and grapes on the lower hills with patches of irrigated vegetables around the village In the summer the flocks would be driven to the higher pastures of the mountains to return to the plains when the autumn rains come (Fig 5 10)

The shape of fields is irregular which are usually polygons and quadrilaterals. The ploughing of fields is done in both directions. If the field is too small, it is ploughed in the square shape.

In the levelled areas of Morocco where cereals are the dominant crops, open fields are found. The fields are scattered, many a times several miles apart. The diversity of soils, inheritance laws and pressure of population on the land have created intense fragmentation of holding in many parts of the Mediterranean lands. The crops are frequently irrigated during the summer season. The small size of holdings and minutely fragmented pattern of small fields are the major problems of this agricultural system.

Mixed Farming or Commercial Crops and Livestock

Mixed farming is a type of agriculture which involves both crops and livestock. This is not to be confused with mixed cultivation, implying merely a series of different crops. It is found throughout Europe—from Ireland in the west through Central Europe to Russia It is also found in North America, east of the 98^0 meridian, in the 'pampas' of Argentina, southeast Australia, South Africa and New Zealand (Fig.5.12). Mixed farming is essentially associated with the density populated, urbanized and industrialized societies, dependent upon high incomes for the sale of its products and upon manufacturing industry for the provision of its inputs. Mixed farming yields fairly high agricultural returns because of efficient methods of farming, excellent transport systems, proximity to the urban markets and reliability of precipitation. The cool-moist summers and comparatively mild-moist winters promote the growth of hay crops and grasses in many undulating tracts and low flat lands. The pastures remain fresh all the year round and large flocks of sheep and herds of cattle are grazed.

The main characteristics of the mixed farming are that farms produce both crops and livestock and the two enterprises are interwoven and integrated. The grass is an important crop of mixed farming system, occupying at least 20 per cent of the cultivated land. In the maritime regions (Wales) grasses occupy up to 75 per cent of the cropped area. The grass is treated with as much care as a cereal or cash crop. The application of fertilizer per hectare of arable land in mixed farming in Northwestern Europe is higher to that of any other part of the

world except Japan. Further, many farms, particularly in Britain and the Netherlands, purchase grains and concentrate to feed their livestock. Moreover, in mixed farming, a number of crops are grown. Cereals dominate the crop land use, the leading grain varying with climate and soil. Wheat in Europe and corn (maize) in the United States dominate the land use pattern. A large proportion of cereals is fed to animals on the farms or sold to manufacturers of feeding stuff. In Denmark, nine-tenths of all grains are fed to livestock and in Sweden three-quarters of all the crops are thus consumed. In Europe a second major category of crops grown are roots, turnips, potatoes and sugarbeet Potatoes are grown as vegetables for feeding pigs and cattle in most of the mixed farming areas of Europe, while in Germany potatoes are sold to distilleries. Sugarbeet is generally sold to sugar factories.

Mixed farms are characterized by high expenditure on machinery and farm buildings, extensive use of manures and fertilizers and also by the skill and expertise of farmers who need to know about all aspects of farming to grow and market their range of products successfully. In mixed farming the average size of holding varies from 10 to 15 hectares in England and 40 to 100 hectares in the United States and Canada These farms are mostly owned and operated by family labour and hired farm labour is rather uncommon. Moreover, tenant farming is usual.

Mixed farming has a three-fold advantage. In the first place, it protects the farmer against the risk of poor prices and disease. In the second place, it spreads labour requirements more evenly throughout the year. Thirdly, it helps in the maintenance of soil fertility if crops are grown in rotation. Instead of growing the same crop in the same field, a succession of different crops is grown which reduces the risk of plant disease.

In mixed farming livestock is fed in a variety of ways The crop produced on the farm is generally fed to cattle and pigs. In winter, forage crops, hay, solid feeds and concentrates are fed to livestock. Livestock feed on crops grown on the farm and graze the pasture. In return their manure helps in maintaining fertility of the land. This system of farming makes a judicious use of the available labour force as livestock require daily attention of the farmer and the family la-

bour. The rising labour cost has, however, made it increasingly difficult to keep a variety of livestock and grow a wide range of crops.

Dairy Farming

The rearing of the cattle for milk and milk products (butter, cheese, condensed and dried milk, etc.) is known as dairy farming. It is mainly practised in Europe, northern USA, Canada, Australia and New Zealand. In Denmark, Netherlands, Belgium, Finland, France and Switzerland it contributes over 40 per cent of the agricultural income (Fig. 5.12).

Although dairying has a long history, the modern dairy industry is the product of last about one hundred years. Apart from cool climate and good pastures, it is largely dependent on good means of transport to supply fresh milk and milk products to the urban places and industrial centres. Nearly 80 per cent of the total milk production of the world is produced in Europe, Russia, Anglo-America, Australia and New Zealand.

In the temperate latitudes, dairying in the most important activity in the areas where climate is too damp for cereal cultivation. Though natural pastures are most important, many farmers keep their cattle under cover in winters.

Dairying is a capital intensive farming. A modern dairy farm needs long hours from the farmer and huge amounts for the development of infrastructural facilities. Capital is required for the purchase of mechanical equipments like milking machines, milk freezers, feeding towers, barns and silos for the storage of fodder for winters.

The size of cattle in dairies varies from country to country and from farm to farm, depending on the size of holding. In the United Kingdom, for example, the ratio of cattle and pasture is one cow after one acre. The excess of cattle on the farm is considered as cruelty towards animals. The average size of dairy cattle in Northwest Europe is only five cows per farm.

Modern methods of dairy farming, cattle breeding and herd management allow high yields of dairy products. A cow in temperate latitudes under normal healthy conditions yields as much as 3000 kg (6900 lbs) of milk per year which fetches a handsome amount to the farmer. The production of milk apart from climate, however, largely

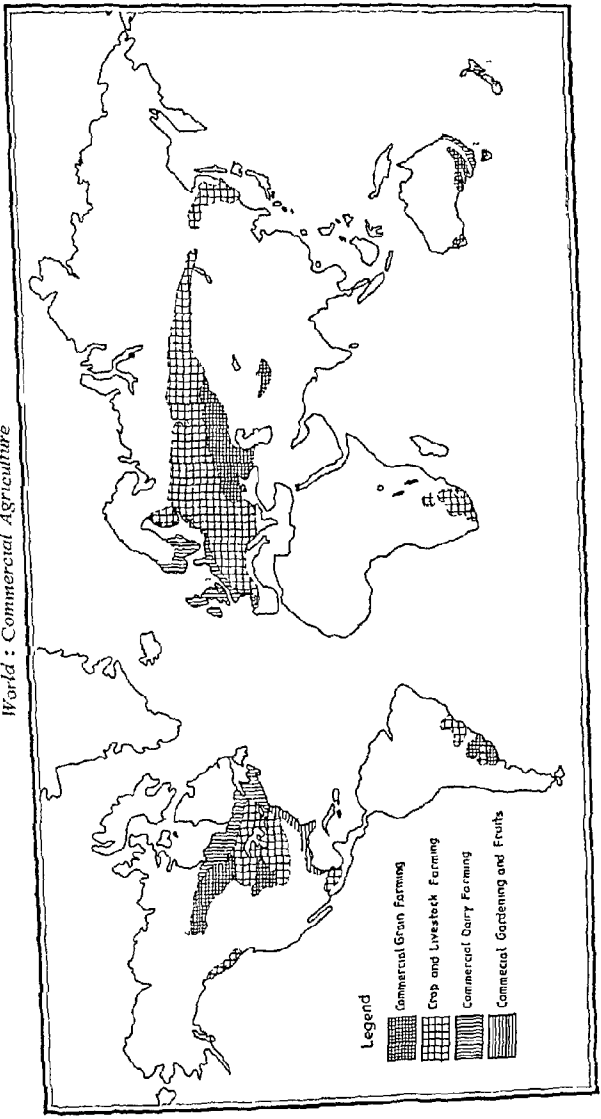


Figure 5.12
World : Commercial Agriculture

depends on the quality of fodder and concentrate feed and breed the cattle. Better feeding not only helps in the increase output l also lengthen the period of lactation.

The countrywise position in some of the dairying countries milk yield per cow per annum has been given in Table 5.11. It will seen from data that the average production of milk per cow per a num varies between 2896 kg in Canada to 4284 kg in Japan. T Netherlands and Denmark stand next to Japan, producing 4207 and 3946 kg milk yield per cow per annum respectively. In t United Kingdom milk yield per cow is 3797 kg while in the Unit States a cow gives about 3767 kg milk annually.

Table 5.11

Milk Yield per Cow 1991-94

Canada	2896 kg
Denmark	3946 kg
Japan	4284 kg
Netherlands	4207 kg
UK	3797 kg
USA	3767 kg

Source· Production Year Book, 1991-94

Regional variations are, however, found in the dairy produ like butter, cream, cheese, dried milk, condensed milk and fre milk. In the vicinity of large industrial cities of UK and USA. t production of fresh milk leads to other dairy products as there heavy demand of fresh milk in the large cities. Fresh milk cannot transported to distant markets as it is the most perishable of the da products New Zealand and Australia concentrate in the product of cheese and butter as the markets of these commodities are at gr distances in the countries of Europe and North America. The av ability and quality of grasses, the prevailing weather, the cow bre and the technology available affect the output of milk and milk pr ucts. The governments of dairying countries are providing enough centives to the dairy farmers to enhance their milk production anc make dairying as an attractive occupation.

Horticulture

Specialized cultivation of vegetables, fruits and flowers is called horticulture In USA it is termed as 'truck farming' as the vegetables and fruits grown far away from the urban and industrial centres are supplied to the markets through the trucks and transport carriers Horticulture is well developed in the densely populated industrial districts of Northwest Europe, Britain, Denmark, Germany, Netherlands, France and Italy (Fig 5 12) In the urbanized developed countries there is heavy daily demand for fresh fruits and vegetables

The Netherlands specializes in the cultivation of spring flowers such as tulips which are flown to all the major cities of Europe, New Zealand, Australia and America In the United States, California is the leading vegetable growing state but horticulture is also important in the Lake Peninsula, Florida and the coastal states of Canada The distance of the truck farms from the markets are governed by the distance a truck can cover overnight Hence, the name truck farming has been given, though some fruits, e g , oranges and apples depend largely on the climatic rather than the market factor

In horticulture the farms are small Such farms are located where communication links with the consumption centres are appreciably good The land in fruits and vegetable gardening is very intensively cultivated The vegetables may be grown in fields or in glass houses Soil fertility is maintained by the heavy application of manures and fertilizers Most of the work is done by hand labour The market gardens are scientifically managed to achieve optimum yields and handsome returns In the developed countries, quality seeds, insecticides, nurseries, artificial heatings and speedy disposal of the commodity are made Owing to these factors the per capita outlay in horticulture is quite heavy

In India, the warm and sunny climate allows the cultivation of a wide range of green vegetables and fruits Flowers, beans, onions, tomatoes, carrots, radish, pumpkins gourd, cabbage, cauliflower and all the leafy vegetables of the warm temperate latitudes are grown in India The seeds of different vegetables are sown in different periods of the year which helps in maintaining a constant supply of vegetables to the urban centres

Although vegetables in India are grown in or around almost

every village, town and city, their cultivation is more important in the outskirts of large urban centres, like Bombay, Calcutta, Madras Delhi, Hyderabad, Bangalore Ahmadabad, Kanpur, Patna Shillong and Gauhati, mainly because of heavy demands In Srinagar (Kashmir) vegetable cultivation is carried on in the Dal lake, mainly during the spring and summer seasons to meet the fresh vegetable demand of Srinagar and its environs A large variety of fruits like mangoes apples, oranges, grapes, bananas, guavas, peaches, berries, apricots, plums, cheeku and diverse dry fruits are grown under the varying agroclimatic conditions of India Mangoes and several other fruits and their products are now being exported to the distant markets of Europe, America, Middle East and the Far East which fetch hand some foreign exchange to the country

Collective Farms

The agricultural systems discussed above were based on the types of crops grown and livestock reared It is also important to assess the effect of the farming organization on agriculture The farming organization is affected mostly by the way in which the land is held, that is whether the farmer owns his farm, or whether he is a tenant or merely a labourer In many countries recent changes have taken place in land tenure, particularly in the socialist countries where farms have been collectivized

Since the Russian Revolution in 1917, radical changes in agricultural practices have taken place in farming in the erstwhile USSR and many other socialist countries including Hungary, Romania, Poland Bulgaria Albania. China, Czechoslovakia, Vietnam, Cuba and North Korea. Collective farming with the set objective to handover the ownership of all farm land to the peasants and to achieve economic self-sufficiency in the basic requirements of food and agroindustries

The communist definition of a collective farm is that it is "a voluntary productive cooperative union based on social ownership of the means of production and on collective labour which excludes exploitation of man by man" In fact, a collective farm is an economic community of farming families who pool their resources and undertake the work together under a management committee, chosen from amongst themselves This committee is responsible for farm management, the allocation of work, the distribution of income in kind and

cash and the disposal of surplus produce. All the working members are placed in labour groups (or brigades) and work is allocated on group basis. The remuneration of collective farmers is calculated in 'work day' unit which means the value of average amount of work that can be done by a collective farmer in one working day, as fixed by a standard quota for each type of work. Differences in skill or special efficiency are remunerated by upgrading some jobs to a higher equivalent in 'work day units'. Each collective farm has to sell the produce to the state at a prescribed rate, a fixed portion of what is assumed to be an average yield.

In the Russian agriculture the two major organizational units employed are the collective (*kolkhoz*) and state (*sovkhoz*) farms. The land of *kolkhoz* is leased in perpetuity to the collective as a unit and is worked under the direction of a committee, selected by the members of the *kolkhoz*. All equipments, livestock and buildings are owned by the collective. Initially, there were no wages as such and payment to the members was made in the form of cash or agricultural produce or both, and used to be calculated in 'work day units'. The work done, the time spent and the skill required were taken into account for the determination and payment of wages.

Since 1966 they have introduced a system of guaranteed monthly cash payment. This ensures payment, whereas in the early system payment was made only if there was a surplus once the other commitments had been made, e.g., state requirements or produce, tax and prices, new equipments, pension and cultural funds. Now members of the collective farms are allowed to retain small plots of land and a few livestock for their personal use. This system is tolerated rather than encouraged, but its value in the agricultural economy cannot be denied.

The *kolkhozs* are highly mechanized and in their operations an important part is played by the Machine Tractor Stations (MTS) maintained by the state at suitable places. These stations keep tractors, combines and harvesters for the use of collective farms which pay in kind at a fixed rate for their services. The average size of collective farms in Russia varies from 250 hectares in the western parts of the country to 2000 hectares in the southcentral Siberia.

State Farms

The state farms (*sovkhozs*) in Russia are owned and operated by the state and their workers are paid employees. State farms are run on highly mechanized basis and obtain the benefits of large scale organization. These farms are generally larger in size and are used in developing new lands. One of the functions of the state farms is to develop new seeds. They have the role of leading and improving agriculture in Russia. However, there are more collective farms than the state farms. State farms tend to be specialist or research units while collectives grow the bulk of Russia's produce. In collective farming the part played by plots allotted to individual farmers is very significant. Their produce consists mainly of potatoes, vegetables, meat, milk, eggs and poultry products and their share in the total national production is significantly high. There is, however, the ever present problem of workers neglecting the community work in favour of working in their own plots.

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6 Agricultural Statistics and Sampling

Geographical Statistics

In general term data are facts, the pieces of information which constitute the raw material of the subject to which they relate. Geographical data have many forms, e.g., altitudes, temperature, pressure, winds, rainfall and evaporation statistics, slope angles, river discharge measurement, population structure, age and sex composition; land values, land use, cropping patterns and yield levels; traffic flow; etc. The list of geographical data is thus quite lengthy. There are, however, two important characteristics of data—geographical or otherwise, which distinguish them from other forms of factual informations : In the first instant, the data are precise and sometimes they are numerical facts. The information which they give is quantitative rather than qualitative. As a result they can be treated statistically with ease and are easy to store, not only as lists of figures on paper, but also on punched cards or in the memory banks of a computer. Secondly, the data are connected with a definite purpose. They represent the result of time-consuming and often costly measurements and surveys. The justification for their collection is their use in testing a theory or hypothesis formulated before hand.

It is difficult to differentiate between geographical data and data used in other disciplines. In general, it may be said that any data is geographical which can help to illustrate relationships, or solve problems of a geographical nature. Despite their diversity, a common fea-

ture of geographical data is that they are spatially distributed, which means that their values differ from place to place. This is true whether the values relate to points (altitude, rainfall, temperature, traffic flow, etc.), lines (fields boundaries, rivers, road density etc.) or areas (crop acreage, crop yields, population density, forest, etc.).

Agricultural Statistics

Data and numerical information have played a very vital role in the growth and development of agriculture, especially in the developed countries. In an agrarian country, like India, having about 70.5 million operation holdings over an aggregate of 162 million hectares, the utility of agricultural statistics is even more important, though it has not been utilized adequately so far. The quantitative agricultural researches, in fact, are largely based on statistical data.

The advent of modern data processing equipments has enabled the agricultural land use planners to utilize new techniques and methodologies and the demands for still more data. The agriculture of a place, in fact, is the result of many physical, social, cultural, economic, institutional, technological, political and psychological forces interacting upon each other and, therefore, the growth, development and problems of agriculture cannot be solved by fractional and isolated approaches. In overcoming these problems, a multidisciplinary approach is required and a large body of data is to be incorporated in any project of research. Thus, the researchers and planners have become increasingly aware of the utility of data. The facts and figures about agriculture, whether they relate to land use, irrigation, forestry, agricultural production, yield and prices of the agricultural commodities are called agricultural data.

The agricultural data refer to information presented quantitatively, that is, figures on the various aspects of agriculture of a macro or micro region. The region may be a country as a whole or a state, or district, or block, or village, or farm, or the field itself. The agricultural data are helpful in estimating, planning and forecasting the agricultural operation of a given unit of area at a given point of time. Agricultural statistics has a very wide coverage and its scope is very widening. The detailed agricultural statistics is required at the national to the village and farm levels for agricultural policy decision, placing agricultural development and estimates of the agricultural

and national income In this chapter the sources and types of agricultural data have been described and the sampling techniques for the processing of data have been illustrated, highlighting the merits and demerits of each of the sampling methods

In order to understand the nature of agricultural statistics more fully, they may be classified into the following major categories

(i) Land utilization and irrigation, including the net area sown, gross cultivated area, current fallow, cultivable waste fallow other than current fallow, other uncultivated land, irrigated area in *kharif* and *rabi* seasons, etc
(ii) Forestry
(iii) Agricultural production—arable, plantations, livestock and fisheries
(iv) Agricultural prices and wages
(v) Statistics relating to agricultural organization and farming structure, e g . persons employed in agriculture, their status, land held under various tenure, number of draught animals, implements, farm building, etc
(vi) Statistics and economics of production and marketing, e g , cost of production, input-output ratio, marketing changes, marketing spreadover, etc
(vii) General statistics, literacy among those employed in agriculture, health, sanitation
(viii) Statistics relating to weather and climate, rainfall and its distribution, temperature and its range, soil and its pH value, etc
(ix) Forecast weather, crops and prices, etc

Land Utilization Statistics

Land utilization statistics provides the area figures, showing distribution of the total geographical area of the country into its various uses The detailed statistics of land utilization in India which mainly gives area of land put to different uses is almost continuously available since 1884

The area of the country has been classified into different categories In 1890-91, a five-fold classification of the total geographical area of the country was made and the land was put under the catego-

ries of (i) forests, (ii) area not available for cultivation, (iii) current fallow, and (iv) net area sown. In 1949-50, the land classification was, however, revised. The revised classification has been accepted of use by all states since 1950-51. The new classification has been introduced by all the states except West Bengal and Manipur where agricultural data are still recorded on the basis of old classification. The prevailing classification of land is as follows:

(i) Forests.
(ii) Land not available for cultivation:
  (a) land put to non-agricultural uses, and
  (b) barren and uncultivated land.
(iii) Other uncultivated land excluding fallow lands:
  (a) permanent pastures and other grazing lands,
  (b) miscellaneous tree crops and groves not included in the net area sown, and
  (c) culturable waste.
(iv) Fallow land·
  (a) fallow land other than current fallow, and
  (b) current fallow.
(v) Net area sown.

The first column in the land use classification as given in the *Indian Agricultural Statistics* (Vol. I) is the geographical area. Total geographical area according to the Surveyor General of India relates to whole of Indian Union. The latest available figures, as furnished by the General Statistical Organization, based on the data released by the Surveyor General of India, are used to show the geographical area.

The reporting area stands for the area for which data on land use classification are available. Where land utilization figures are based on land records, reporting area is the one according to village papers, i.e., the papers prepared by the village *patwari*. In some cases, the village papers may not be maintained in respect of the entire area of the state. For example, such papers are not prepared for the forest area, though the magnitude of such area is known.

Area under forests includes all actually forested areas or land

classed or administered as forests under any legal enactment dealing with forests whether state-owned or private. If any portion of such land is not actually wooded or put to some agricultural use that portion is included under the appropriate head of cultivated or uncultivated land.

Area not Available for Cultivation

(a) *Land put to non-agricultural uses* : This stands for all lands occupied by buildings, industrial undertakings, roads and railways or under water, e.g., rivers and canals and all other lands put to any other non-agricultural uses.

(b) *Barren and uncultivable land* : This covers all barren and uncultivable lands like mountains, deserts, etc. Lands which cannot be brought under cultivation without incurring costs on their development are classed unculturable, such lands could be outside or within cultivated holding.

In Rajasthan, land classified under this head lies mostly in the Thar desert, where the soil is sandy and rainfall is below 50 cm (20 inches). In other states, they are generally in districts where the topography is hilly or is covered with laterites or such soils as are highly infertile, stony and coarse, and the rainfall is insufficient, so that it is hardly possible to develop or cultivate these lands at a reasonable cost.

Other Uncultivated Land excluding Current Fallow

It included permanent pastures and other grazing lands, miscellaneous tree crops, groves and culturable waste. The permanent pastures and other grazing lands cover all grazing lands, whether they are permanent pastures and meadows or not. The common land in the village and grazing land within the forest areas are included under this head. The miscellaneous tree crops and groves are grown in the areas not included in the net area sown. All the culturable land put to some agricultural use, but not included under 'net area sown', is included under this class. The lands under thatching grasses, bamboo bushes and other groves trees for fuel, etc., which are not included under orchards, are placed under this category. The culturable waste included lands available for cultivation, whether or not taken up for cultivation

or abandoned after a few years for one reason or the other. Such lands may be either fallow or covered with shrubs and jungles which are not put to any use. They may be assessed or unassessed and may be in isolated blocks or within cultivated holdings. The land, once cultivated but not cultivated for five years in succession, is included in this category. It is a sort of residual class which includes all uncultivated lands not accounted for by any other class.

Fallow Lands

The fallow lands, other than current fallow, include all lands which were taken up for cultivation but are temporarily out of cultivation for a period of not less than one year and not more than five years. The reason for keeping such land fallow may be one of the following:

(i) inability of farmers to cultivate or lack of means,
(ii) inadequate water supply;
(iii) malarial climate;
(iv) silting of canals and rivers;
(v) soil erosion; and
(vi) unremunerative of farming.

Against this, the current fallow comprises cropped areas which are kept fallow during the current year. For example, if seedling area is not cropped again in the same year it is treated as current fallow There is, however, a close relationship between the fallow lands and the net area sown. Good and timely rainfall, weather conditions, prices of agricultural commodities, political stability, security of tenure and tenancy conditions help in increasing the area sown, which represents the actual physical area under crops and orchards. The area cropped more than once is counted only once. Thus, the gross cropped area or total cropped area represents the sum total of area under all crops. The difference between the total cropped area and net area sown is accounted for by the area sown more than once on the same land during the same year with the same or different crops.

Indian Agricultural Statistics

The land utilization statistics of India is published in the annual publication, entitled *Indian Agricultural Statistics*, issued by the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, New Delhi. Its first volume contains summary tables relating to land utilization for the Indian Union as a whole and for each of the states and the union territories. The major categories of land use columns given in this volume are as follows:

(i) total area under classification of area;
(ii) area irrigated in the *kharif* and *rabi* seasons and the crops irrigated; and
(iii) area under each of the crops cultivated in the country. There are 30 crops in all cultivated in the country. The cereal and non-cereal crops are given in separate groups.

The second volume furnishes statewise and districtwise figures of classification of area, area irrigated, and area under crops. The summary tables give all-India figures for ten years. The statewise figures are for five years and districtwise figures for two years. The information about states is based on returns received from the state governments concerned.

Agricultural Season and Crop Reports

While the all-India land utilization statistics is published in the *Indian Agricultural Statistics*, the individual state publishes this statistics in respect of their states in the Season and Crop Reports, which besides land utilization statistics give figures for area and production of crops, area irrigated and sources of irrigation, livestock statistics, prices, etc.

The fully revised data on total cropped area and its distribution by specific crops are normally available with a lag of two years. This delay makes the utility of land use statistics limited. The detailed statistics of land use which mainly gives area of land put to different agricultural uses is available almost continuously from 1887-88, although average of these statistics has been changing from time to time and their scope gradually expanding. The present coverage of

land use and crop statistics is about 94 per cent of the total area of the country.

The area statistics figures generally relate to the agricultural year ending 30 June, but in the case of Assam and Madhya Pradesh, they relate to the years ending 31 March and 31 May respectively.

Area Statistics

The coverage statistics of the distribution of gross cropped area by crops are published in the *Agricultural Statistics of India*. This publication is based on the information contained in the Season and Crop Reports, issued annually by the state governments. Before independence, the coverage of crops was not only incomplete but it also differed from crop to crop. The forecasts covered only those states where the crop was grown at an appreciable extent and where facilities for reporting were available. The conventional estimates of coverage and production of these crops in respect of non-reporting areas were developed in the interest of complete coverage for the country. The coverage of food crops in complete from the year 1948-49. The geographical coverage of commercial crops is now much larger than before and is fairly complete in respect of important ones.

The statistics of irrigated area under these crops is also available now. The scope of the group of crops known as condiments and spices has also been enlarged. The general head 'oilseeds' has been split up into edibles and non-edibles; sesamum, rape and mustard, coconut and groundnut being considered as edible and linseed as well as castor being treated as non-edibles. The classification of crops is fairly detailed and separate figures are now published in respect of the following groups and subgroups.

Crop Statistics

Here is the classification of crops for which area and production statistics are published:

I.(a) *Food Crops* :

(i) Cereals : rice—autumn, winter, summer and total jowar kharif, rabi and total, bajra, maize, ragi, wheat, barley, other cereals and small millets-kharif and rabi and total, total cereals and millets.

(ii) Pulses gram, tur or arhar (pigeon-pea), other pulses khariff, rabi and total, total pulses Total foodgrains

(b) Sugar, sugarcane, others, total

(c) Condiments and pepper (black), chillies, ginger turmeric, cardamoms, betelnuts, others, total spices

(d) Fruits and vegetables including root crops Fruits dried, cashewnuts, fresh mangoes citrus fruits, bananas, grapes, others

Root crops : Vegetables, potatoes, tapioca, sweet potatoes, onions, other kharif and rabi vegetables

(e) Other food crops

II *Non-food Crops*

(a) Oilseeds : groundnuts, castor, sesamum (till), rape and mustard, linseed, coconut, others, total

(b) Fibres cotton, jute, mesta, sunhemp, others total

(c) Dyes and tanning materials indigo, others, total

(d) Drugs and narcotics : opium, coffee, tea, tobacco, cinchona, Indian hemp, others, total

(e) Food crops

(f) Green manuring crops.

(g) Other non-food crops

Area and production statistics is published in the '*Estimates of Area and Production of Principal Crops*', published by the Directorate of Economics, Ministry of Food and Agriculture, Government of India It is published in two volumes—'Summary Tables' and 'Detailed Tables'. While Summary Tables are issued around the end of a calendar year, there is a sufficient time lag in the publication of the volume dealing with Detailed Tables

Area Under Mixed Crops

Sowing of two or more crops in mixture is practised more or less all over India The problem of correct recording of area under mixed crops becomes difficult on account of the fact that even within a state or district, cultivators practise quite a large number of mixtures There is also a considerable variation in the proportion of seeds of the components sown in the case of the same type of mixtures from

area to area and even from field to field. The methods of sowing of mixtures also do have a degree of variance. The mixtures may be sown either broadcast or in rows, the number of rows of crop alternating with those of another crop may also vary.

Table 6.1

Ratio Fixed for Apportionment of Net Areas of Component Crops of the Mixture

State	*Wheat-gram*	*Wheat-linseed*	*Gram-linseed*	*Wheat-barley*	*Gram-barley*
Uttar Pradesh	50 50			50.50	75 25 to 50 50
Madhya Pradesh	90 10 to 50 50	95:5 to 50 50	95:5 to 20 80		
Punjab	50 50			50 50	50 50
Bihar	50 50			50.50	50 50
Rajasthan	70.30			66·34 to 36:66	50 50 to 44 60

Deficiencies in the Crop Acreage Data

Improvements have been made in the assessment of crop data and their recordings, yet they suffer from certain deficiencies which are as follows:

(i) There are areas for which no agricultural statistics is as yet reported. The statistics of acreage would remain incomplete until every bit of land is measured and reported. This will be possible only when every village in the union is surveyed and mapped cadastrally. In many of the hilly states and union territories, especially that of the Northeastern India where shifting cultivation is practised, cadastral maps have not been prepared so far. As a result of which statistics for the entire area under cultivation is not reliably available.

(ii) The acreage data, available for the various states, are not at the uniform standard.

(iii) For some of the crops no forecast is issued and as such crops

occupy insignificant area

(iv) No reliable estimate of area under the various tree crops is available at present The information available is purely subjective

(v) No satisfactory formula has so far been evolved to apportion area under a crop-mixture (mixed crops) into its constituents Some confusion still prevails in the matter of estimating the area under the field boundaries

Irrigation Statistics

The distribution of rainfall in the country is uneven and over the period of time, it is highly varying over the greater part of the country To overcome the problems of rainfall deficiency and short supply of water to crops, irrigation provisions in the form of canals, wells, tubewells and tanks have been made The crops and area irrigated also differ from region to region and from year to year A gap between the normal rates of out-turn of area irrigated and unirrigated excluding areas of assured rainfall is so wide that for a proper assessment of the production potentialities, it is essential to have separate figures for irrigated and unirrigated areas, according to different sources of irrigation and also according to crops In India, statistics of irrigation is collected along with the land utilization In using these data, it must be remembered that besides the area under irrigation, there are other areas which have assured an adequate rainfall and which are now classed as unirrigated land Further, the mere fact that a certain area was irrigated does not necessarily imply that the irrigation water was adequate All-India statistics for irrigation is available for the following

(i) net area irrigated sourcewise,

(ii) gross area irrigated (sourcewise breakup not available), and

(iii) distribution of gross irrigated area among various crops

The Land Revenue/Land Record Department and Irrigation/Public Works Department compile the irrigation data Under the instructions of the Union Ministry of Agriculture, the states are required to collect the following statistics

(i) crop acreage, irrigated and unirrigated;
(ii) source of irrigation — canals, tanks, tubewells and others, their classification according to ownership, i.e., whether owned by the respective government or by private persons;
(iii) classification of wells into masonry or non-masonry, in use or abandoned, whether used for irrigation or domestic purpose etc.;
(iv) method of water supply, lift or flow, lift by electric pump or oil engine or traditional devices; and
(v) capacity of irrigation and extent of irrigated area—for a canal, mileage; for a tank whether the *ayacut* exceeds 40 hectares or less, and for a well, whether it is an independent *ayacut* or it supplements other sources of irrigation.

Statistics of Major Inputs

Besides irrigation, other major inputs are fertilizers, seeds, plant protection, machinery and credit which have been discussed here. The data on the absorption of various kinds of fertilizers are obtained by periodic reports from the state governments. These reports provide information on the initial stocks of fertilizers, the receipts and sales during the period and the closing stocks. Fertilizer statistics publication started in 1956 and data are available up to 1971-72.

Agricultural Prices

The term 'agricultural prices' covers wholesale, retail and harvest prices of agricultural commodities as well as those of livestock products. The price data, at present, are being collected by a number of agencies. The major data collecting agencies are:

1. Directorate of Economics and Statistics, Ministry of Food and Agriculture.
2. Directorate of Marketing and Inspection.
3. Indian Labour Bureau, Ministry of Labour.
4. National Sample Survey.
5. Commodity Committees concerned with agricultural commodities.
6. State Revenue, Agriculture and Marketing Departments and Statistical Bureau.

The major publications on prices are as follows:

1. Bulletin of Agricultural Prices.
2. Wholesale Prices of Foodgrains (Weekly)
3. Agricultural Prices in India (Annual).
4. Agricultural Situation in India (Monthly Journal).
5. Farm Prices of Principal Crops (Agricultural Prices in India, 1954).

The Directorate of Economics and Statistics, Ministry of Food and Agriculture has adopted the following techniques for the existing index series of agricultural statistics:

(i) Index of area under crop $= \frac{\Sigma a_{ij}}{\Sigma a_{i0}} \times 100$

(ii) Index of net area sown $= \frac{N_j}{N_0} \times 100$

(iii) Index of cropping pattern $= \frac{\Sigma c_{ij}\ y_{i0}\ p_{i0}}{\Sigma c_{i0}\ y_{i0}\ p_{i0}} \times 100$

(iv) Index of yield $= \frac{\Sigma a_{i0}}{\Sigma a_{ij}} \frac{y_{ij}}{y_{i0}} \frac{p_{i0}}{p_{ij}} \times 100$

(v) Index of productivity per hectare of net area

$$= \frac{\Sigma a_{ij}}{\Sigma a_{ij}} \frac{y_{ij}}{y_{i0}} \frac{p_{ij}}{p_{i0}} \int \frac{N_j}{N_0} x\, dx \times 100$$

where,

a_{i0} = Area under the ith crop in the base period

a_{ij} = Area under the ith crop in the jth year

N_o = Net area shown in the base period

N_j = Net area shown in the jth year

y_{i0} = Yield per hectare of the ith crop in the base period

y_{ij} = Yield per hectare of the ith crop in the jth year

p_{i0} = Price per unit of the ith crop in the base period

p_{ij} = Production of the ith crop in the jth year

Other Statistics

In addition to the agricultural statistics, data are also recorded for the rainfall, size of holding, ownership, tenancy and market intelligence. These additional data can be obtained in the following areas:

(i) Rainfall—Crop Calendar and Agricultural Atlas
(ii) Number and size of cultivators holding and details of ownership and tenancy—Land Revenue and Land Record Office
(iii) Market intelligence
(iv) Market surplus
(v) Stocks
(vi) Feed, seed and wastage rates
(vii) Capital output and cost benefit ratio
(viii) Demand projections
(ix) Input-output ratio
(x) *Private agricultural investment*
(xi) Animal husbandry
(xii) Agricultural trade

World Agricultural Statistics

The Food and Agricultural Organization's *Production Year Book* has been designed to report annually the world agricultural statistics and more of agricultural statistics are also available in the following publications:

1. United Nations Statistical Year Book
2. FAO Production and Trade Year Book
3. FAO Year Book of Forest Product Statistics
4. FAO Year Book of Fishery Statistics
5. FAO Monthly Bulletin of Agricultural Economics and Statistics
6. FAO State of Food and Agriculture
7. United Nations World Economic Survey of Asia and the Far East
8. United Nations Monthly Bulletin of Statistics

Fieldwork

Traditionally used in geography as a generic term to cover the methods by which primary data were obtained. These methods included the preparation of maps, observation and surveys of land uses, urban morphology, etc. Geographers, at present, largely concentrate on the published or secondary data and the primary data or information generated by doing fieldwork. In the collection of primary data, the fieldworker learns about habitat, terrain, space and people and studies behaviour, events and activities as they occur. The primary data are those which are collected afresh and for the first time and thus happen to be original in character. The secondary data, on the other hand, are those which have already been collected by someone else and which have already been passed through the statistical process.

Collection of Primary Data

Primary data may be collected either through observation or through direct communication with respondents in one form or another through personal interviews. There are several ways of collecting primary data. These may be: (i) observation method, (ii) interview method, (iii) questionnaire method, and (iv) schedule method.

Observation Method

In observation method, the information is sought by way of investigator's own direct observation without asking from the respondent. The main advantage of this method is that it is free from subjective biasness, as it is free from respondents willingness. It is, however, an expensive and time consuming method. Moreover, the information provided by this method is very limited and some of the more busy people like executives may not be accessible to direct observation.

Interview Method

Primary data may be collected either through personal interviews or through telephonic interviews:

(a) In the personal interviews the interviewer asks questions generally in a face to face contact. Through interview method more and reliable information may be obtained. Personal information can be obtained easily under this method. It is, however, a very expensive and time consuming method, especially when large and widely

spread geographical sample is taken. Certain types of respondents, such as officials, executives or people of high income groups, may not be easily accessible. In this method, the respondent may give wrong and imaginary information. For effective interview there should be a good rapport with respondents which is often very difficult to develop. For a good result the interviewer's approach should be friendly, courteous, conversational and unbiased for which a proper training is required.

(b) In telephonic interviews contact is made with the respondents through telephone. The main merits of telephonic interviews are:

(i) It is more flexible and faster than other methods.
(ii) It is cheaper and less time consuming.
(iii) Recall is easy and replies can be recorded without causing embarrassment to respondents.
(iv) At times, access can be made to respondents who otherwise cannot be contacted for one reason or the other.
(v) No staff is required and wider representation of sample is possible.

This method also has several weaknesses. For example, the surveys are restricted to respondents who have telephonic facilities and little time is given to respondents for considered answers. It is not suitable for intensive surveys where comprehensive answers are required for various questions.

Questionnaire Method

In this method a questionnaire is mailed to the person concerned with a request to answer the questions and return the questionnaire. This method is most extensively applied in various researches of human and economic geography. The main merits of this method are given below:

(i) There is low cost even when the universe is large and is widespread geographically.
(ii) It is free from bias of interviewer as answers are respondent's own words.

(iii) Respondents, who are not easily approachable, can also be reached conveniently Moreover, respondents are given enough time to give well thought answers

The main demerits of this method are

(i) Low rate of return of the duly filled questionnaires
(ii) It can be used only when the respondents are educated and cooperative
(iii) The control of the questionnaire may be lost once it is sent
(iv) It is difficult to know whether willing respondents are truly representative
(v) This method is likely to be the slowest of all

Schedule Method

This method of data collection is very much like the collection of data through questionnaires, with little difference that lies in the fact that schedules (proforma containing a set of questions) are being filled in by the enumerators who are specially appointed for this purpose Enumerators explain the aims and objects of the investigation and also remove the difficulties which any respondent may feel in understanding the implications of a particular question

This method is very useful in extensive enquiries and can lead to fairly reliable results It is, however, very expensive and is usually adopted in investigations conducted by governmental agencies or by some organizations Population census all over the world is con ducted through this method

For the selection of an appropriate method, the objective, nature and scope of study, the availability of time and funds, and the level of precision required are to be taken into consideration

Land Use Survey Techniques

Land use survey is done to classify land according to the utilization made of it For agricultural and urban land utilization and land use planning it is of immense help With the increase in population and development of technology there is much demand of land which is finite in character Consequently, various economic activities compete

for the demand of land. Land use studies have been more commonly carried out in the past in rural areas, but now there is enough stress on urban land use studies also. Land use survey is, however, an expensive and time consuming activity which demands a team of skilled surveyors, enumerators and workers.

Land use surveys may be conducted either by (i) proximate sensing technique, or (ii) remote sensing technique.

Proximate Sensing Technique

In the proximate sensing technique, the maps, diagrams and sketches are drawn by measuring the land with the help of survey equipments. Preparation of layout plans and topographical maps may be cited as some of the examples of proximate survey technique. The main advantage of the proximate land use survey is that it brings the surveyor in close contact with the ground reality, i.e., the earth surface. The changes, if any, may also be recorded on the spot. The topographical maps, however, provide very little information about the use of land. Moreover, such survey can be done only with the help of skilled and trained persons. It is a time consuming technique for which a lot of funds should be available.

Remote Sensing Technique

Remote sensing is a technique developed in recent years for the preparation of land use maps. It is a kind of technique which gives quick results and reduces unnecessary fieldwork. The most popularly used remote sensing technique to prepare land use maps is the aerial photography survey. In recent years, the satellites or spacecraft fitted with various remote sensing appliances like electrooptical and non-photographic sensors have added a new dimension to these techniques. The satellite imageries are prepared with the help of remote sensing techniques. These imageries enable researchers to prepare inventories of the natural resources and to classify land use data more accurately and rapidly than is possible by using aerial photographs. The satellite imageries are of great help in making agricultural land use maps which serve as the basic tools for regional planning and development.

Need for Sampling

Sampling is used in practice for a variety of reasons Important amongst them are

1 Sampling can save time and money A sample study is usually less expensive than a census (total) study and produces results at a relatively faster speed
2 Sampling may enable more accurate measurements for a sample study is generally conducted by trained and experienced investigators
3 Sampling remains the only way when population (universe) contains infinitely many members
4 Sampling remains the only choice when a test involves the destruction of the item under study
5 Sampling usually enables to estimate the sampling errors and, thus, assists in obtaining information concerning some characteristic of population (universe)

Some Fundamental Concepts

In the following paragraphs some of the fundamental concepts pertaining to sampling have been explained

Universe/Population

From a statistical point of view, the term 'universe' refers to the total of the items or units in any field of enquiry, whereas the term 'population' refers to the total of items about which information is desired The attributes that are the object of study are referred to as characteristics and the units possessing them are called as elementary units The aggregate of such units is generally described as population Thus, all units in any field of enquiry constitute universe and all elementary units (on the basis of one characteristic or more) constitute population Quite often, we do not find any difference between population and universe, and as such the two terms are taken as interchangeable However, a researcher must necessarily define these terms precisely

The population or universe may be finite or infinite The popula-

tion is said to be finite if it consists of a fixed number of elements so that it is possible to enumerate it in its totality. For example, the population of a city, the number of households in a village, the number of workers in a factory, and the number of students in a university are the examples of finite population. The symbol 'N' is generally used to indicate how many elements (or items) are there in case of a finite population. An infinite population is that population in which it is theoretically impossible to observe all the elements. Thus, in an infinite population, the number of items is infinite, i.e., we cannot have any idea about the total number of items. For example, the number of stars in the sky, sand particles at a sea beach, and pebbles in a riverbed. From a practical consideration, the term 'infinite population' is used for a population that cannot be enumerated in a reasonable period of time. This way we use the theoretical concept of infinite population as an approximation of a very large finite population.

Sampling Frame

The elementary units or the group of cluster of such units may form the basis of sampling process in which case they are called as sampling units. A list containing all such sampling units is known as sampling frame. The sampling frame consists of a list of items from which the sample is to be drawn. For instance, one can use telephone directory as a frame for conducting opinion survey in a city. Whatever the frame may be it should be a good representative of the population.

Sampling Design

A sample design is a definite plan for obtaining a sample from the sampling frame. It refers to the technique or the procedure the researcher would adopt in selecting some sampling units from which inferences from the population are drawn. Sampling design is determined before any data is collected.

Statistic(s) and Parameter(s)

A statistic is a characteristic of a sample, whereas a parameter is a characteristic of a population. Thus, when we work out certain measures such as mean, median, mode, etc., from samples, they are called statistics for they describe the characteristics of a sample. But when

such measures describe the characteristics of a population, they are known as parameters. For example, the population mean (μ) is a parameter, whereas the sample mean ($\bar{X}$) is a statistic. To obtain the estimate of a parameter from a statistic constitutes the prime objective of sampling analysis.

Sampling Error

Sampling survey does imply the study of a small portion of population and as such there would naturally be a certain amount of inaccuracy in the information collected. This inaccuracy may be termed as sampling error or error variance. In other words, sampling errors are those errors which arise on account of sampling and they generally happen to be random variations (in case of random sampling) in the sample estimates around the true population values. It can be numerically described as under:

Sampling error = Frame error + chance error + response error.

Precision

Precision is a range within which the population average (or other parameters) will lie in accordance with reliability specified in the confidence level as a percentage of the estimate ± or as a numerical quantity. For example, if the estimate is Rs. 4000 and the precision desired is ± 4 per cent, then the true value will be not less than Rs. 3840 and not more than Rs. 4160. This is the range (Rs. 3840 to Rs. 4160) within which the true answer should lie. But if we desire that the estimate should not deviate from the actual value by more than Rs. 200 in either direction, in that case the range would be Rs. 3800 to Rs. 4200.

Confidence Level and Significance Level

The confidence level or reliability is expected percentage of times that the actual value will fall within the stated precision limit. Thus, if we take a confidence level of 95 per cent, then we mean that there are 95 chances in 100 (or .95 in 1) that the sample results represent the true condition of the population within a specified precision range against five chances in 100 (or .05 in 1) that it does not. Precision is the range within which the answer may vary and still be acceptable; confidence level indicates the likelihood that the answer

will fall within that range, and the significance level indicated the likelihood that the answer will fall outside that range. It may be remembered that if the level of confidence in 95 per cent, then the significance level will be (100-95), i.e., 5 per cent, if the confidence level is 99 per cent, the significance level is (100-99), i.e., 1 per cent, and so on.

Techniques and Methods of Sampling

Geography, dealing with the man and environment relationship, is essentially a social science. One of the main problems that geographers meet in their pursuit of research is the abundance of data As a matter of fact, in the recent decades, an 'explosion of data' has taken place in every sphere of life, providing an enormous source of valuable information in the form of numerical facts for the quantification of socioeconomic problems in space and time. The increased quantity of data, though useful for the formulation of hypotheses and their testing, has created the problems of data processing, its plotting on maps and analysis. The task of researchers has, thereby, been rendered arduous, costly and time consuming.

Almost all the branches of geography, e.g., geomorphology, climatology, oceanography, pedology, demography, economic, agricultural and industrial geography, urban and rural land use planning, transport, urban settlement, electoral and medical geography have all turned to more precise numerical data in their attempts to render a more realistic and objective assessment of geographical phenomena. Moreover, now geographers are increasingly cooperating with scientists of other disciplines. Application of sound and sophisticated statistical techniques to geographical data has, therefore, become essential.

'Sampling' is a useful technique for the processing of data. It is frequently used by geographers in their studies. Sampling of data in itself is a tedious job which requires utmost care on the part of researcher to arrive at reliable results The essence of sampling lies in the fact that a large number of items, individuals, or locations (statistical population) may, within specified limits of statistical probability, be presented by a smaller group of items (a sample) selected from the larger group (a parent population). Out of the huge population, if a limited selection of items or cases is made, it is called a

'sample' The limited 'sample' is generally sufficient for making a generalization about the whole population In many cases, the number of individuals in the population, e g , the average yield of all the plots of an agricultural region or the pebbles on a sea-beach are so numerous that measuring of all of them would be almost impossible from a practical point of view But, if through sampling, a limited selection of fields for the measurement of yields would enable the observer to obtain the average yield of the fields in the entire region, similarly, a limited selection of pebbles on the sea-beach will be sufficient for making a generalization about the pebbles on that coast Sampling, thus, represents a more efficient use of our energy, still allowing us to make reliable statements about the whole population Public opinion polls announce how a nation intends to vote, or analyse people's attitudes on current issues, but their conclusions are obtained from a sample consisting of a few hundred questionnaires, rather than by consulting everyone in the country Complete enumeration of population in most of the cases is almost impracticable An appropriate sampling in geographical research is highly desirable as it saves time, efforts and cost appreciably and gives reliable results which can be used for the purpose of generalization and forecasting

The problem of choosing the right size of sample, however, is a little more complicated The simplest rule is that the larger the size of sample, the more likely it is to give a reliable picture of the parent population As a further rough guide it can be said that the size of sample should be at least 5 per cent to 15 per cent of the total for satisfactory results The decisions on defining parent population and choosing the best sampling method, however, depend to a large extent on commonsense

Some of the commonly known and frequently used methods of sampling are random sampling, purposive sampling, systematic sampling, stratified sampling and multistage sampling

Random Sampling

In the random sampling, the sample units are selected at random Once the 'parent population has been defined, each item in that population has an equal chance of being included in any sample In this method, proper care has to be taken to ensure that samples are selected at random Many a time a truly random choice may not be fea-

sible. The investigator should, however, pursue the ideal of random selection as closely as possible. The use of lottery is the simplest method of such sampling. Fairly good samples can also be taken by the use of random sampling numbers given in Table 6.2.

Table 6.2

Random Number Table

20	17	42	01	72	33	94	55	89	65	58	60
74	49	04	27	56	49	11	63	77	79	90	31
94	70	49	49	05	74	64	00	26	07	23	00
22	15	78	49	74	37	50	94	13	90	08	14
93	29	12	20	26	22	66	98	37	53	82	62
45	04	77	48	87	77	66	91	42	98	17	26
44	91	99	08	72	87	33	58	12	08	91	12
16	23	91	95	97	98	52	49	40	37	21	46
04	50	65	37	99	57	74	98	93	99	78	30
32	70	17	05	79	58	50	26	54	30	01	88
03	64	59	55	85	63	49	46	61	89	33	79
62	49	00	67	28	96	19	65	13	44	78	39
61	00	95	85	86	94	64	17	47	67	87	59
89	03	90	40	10	60	18	43	97	37	68	97

The sampling with the help of random sampling table may be illustrated by citing an example. Suppose for the study of agricultural land use of a region having 400 villages, only 15 villages are to be selected at random.

To begin with the villages will be serially numbered, e.g., 1,2,3,4,5.....400. After arranging the villages in a serial order, a page (table) of the random sampling series will be taken. Starting with any figure of that page, the digits occurring in succession (either in rows or in columns) will be written down in blocks of three to give three digit numbers. The number 001 and 002 may be taken to correspond to village 1 and village 2 respectively and finally 400 will correspond to village 400. All the three digit numbers greater than 400 and also 000 will be ignored. If a number occurring earlier is repeated, a new digit number will be taken until 15 different three digit numbers (none of which should be 000 or greater than 400) are obtained. The

following example illustrated with the help of Table 6.3 would make the point more clear.

Total number of villages in the area under study for land use	400
Number of villages to be selected (samples) for study	15

The Table 6.2 is given in the values of tens and ones. First, these figures are arranged in blocks of three to give three numbers, as the total number of villages of the area under study goes up to three digits (400). Then, all figures which are within 400 are selected, ignoring the figures which exceed 400 and also 000. According to the said technique, the 15 sample villages, taken with the help of Table 6.2, will be as follows 201, 221, 162, 327, 36, 17, 157, 290, 47. 239, 09, 39, 335, 196. Arranged in a serial order the villages chosen as samples will be 9, 17, 36, 39, 47, 157, 162, 196, 201, 221, 239, 275, 290, 327, 335.

Table 6.3

Random Sample Village

201*	364*	919	640
744	624	239*	509
947	610	506	669
221*	890	701	669
932	174*	645	335*
450	490*	490	524
449	704	009*	749
162*	157*	039*	502
452	290*	642	494
327*	047*	490	196*

*Selected villages

Again, if the full list was made up of 10000 villages, the first four columns of the random sampling table would be used, 0000 representing 10000. For a selection of 15 villages in this case, the first sample would be the one numbered 2017 (see Table 6.2) on the full list, the next would be number 7449 and so on, until the full list of 15 villages is selected. In this case, the figures exceeding 10000 and

0000 shall be ignored while making the selection. The random sampling table facilitates the work of researchers. The main advantage of the random sampling technique lies in the fact that it is unbiased, more objective and representative of the whole book of data

Purposive Sampling

In the purposive sampling technique, the samples are selected with a definite purpose in view. For example, if the standard of nutrition of the rural population of a region or country, having vegetarian food habits, is to be determined, only the vegetarian food eating families will be taken as the samples for study. Similarly, if the change in the standard of living of the agricultural labourers and farmers of a component areal unit during a specific period of time is to be studied, the samples will be taken from the respective categories, ignoring the rest of the population. This technique of sampling suffers from the drawback of favouritism and fails to give a representative sample of the population.

Systematic Sampling

In this method, a regular pattern of selection is made instead of choosing each individual separately. This method is also known as quasi-random. For instance, if a study of crop combination is to be made in 2000 villages of an areal unit and 20 sample villages are to be selected, the villages should be given a serial order, starting from 1 to 2000. After arranging the villages serially, every hundredth village of the list be chosen. The required sample villages will be reached quickly. If used sensibly, systematic sampling can often be more convenient than true random sampling and can be equally effective. This method, though helpful in making quick and effective sampling, however, suffers from the setback of subjectivity as each village of the area does not have an equal chance of being included in the sample.

Stratified Sampling

When the population is heterogeneous with respect to variables under enquiry and can be divided into relatively homogeneous groups and subgroups, a stratified sampling technique can be adopted. This type of sampling is mostly applied when there are significant groups

of known size within the 'parent population' and it is desirable to make sure that each subgroup is fairly represented within the total sample. For example, suppose the population of a village is 10000 and on the basis of income variables, it is divisible into 10 groups, then a random sample for each of the subgroups will be taken representing the income of the respective group The main advantage of the stratified sampling lies in the fact that it can be administered easily and each stratum is represented in the sample (which may not be the case in random and purposive sampling), so that, if required, one can have separate estimates for stratum means Stratified random sampling is widely used in agricultural, industrial and applied geographical researches.

Multistage Sampling

When the required sampling unit is reached through stages, it is called multistage sampling For example, if 1000 families are to be selected for a land tenancy or socioeconomic survey of a meso or macro region, this can be done through multistage sampling, i.e., by first selecting a number of villages of the areal unit at random, and then selecting a number of families from each of the selected villages This method of sampling is particularly useful for population covering large areas for which a list of individuals is not readily available or cannot be easily constructed. The method in general is cheaper but less accurate in comparison to the corresponding one of single stage sampling.

The statistical techniques of sampling described above are of great utility for researchers, dealing with the socioeconomic problems of the society and also for those who are working in the fields of evolution of land forms, climatology, hydrosphere, etc. The application of sampling techniques in geographical researches facilitates the task of researchers as they save time, efforts and cost appreciably and give fairly reliable results. In geography, in which graph theory, correlation, topology and transformation are at the emergent stage, sampling techniques have a significant role in the formulation of hypothesis, decision making, simulation and forecasting.

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7 Agricultural Regionalization

Region is one of the basic concepts of geography. It has been defined differently by different geographers. A widely accepted definition of region is "an area that is differentiated from other areas according to the specified criteria". It has also been defined as "a differentiated segment of the earth surface" (Whittlesey,1929). Whatsoever the definition of region may be, it is a device of area generalization.

Geographers identify regions based on physical and cultural characteristics. The landform regions, climatic regions, rainfall regions, pedological regions and biotic regions are some of the examples of physical regions, while population regions, linguistic regions, industrial regions, agricultural regions and trade and commerce regions are the examples of cultural regions. The present chapter deals with the concept of agricultural region. The main techniques used for the delineation of agricultural regions have also been examined

Agricultural region is an uninterrupted area having some kind of homogeneity with specifically defined outer limit Agricultural region, in fact, is a device for selecting and investigating regional groupings of the complex agricultural phenomena found on the earth surface. In other words, any segment or portion of the earth surface possessing a distinctive form of agriculture is an agricultural region. Its homogeneity is determined by the criteria adopted. Thus, an agricultural region is a dynamic concept which changes in space and time.

The main characteristics of agricultural region are : (i) they have location, (ii) they have transitional boundaries, (iii) they may be either formal or functional, and (iv) they may be hierarchically arranged.

Delimitation of Agricultural Rigions

Since the boundaries of agricultural regions are transitional and not sharply dividing lines, their precise delimitation is a difficult task The main techniques used by geographers for the delimitation of agricultural regions are (i) empirical technique, (ii) single element technique, (iii) multi-element (statistical) technique, (iv) quantitative-cum-qualitative technique, and (v) normative technique.

Empirical Technique

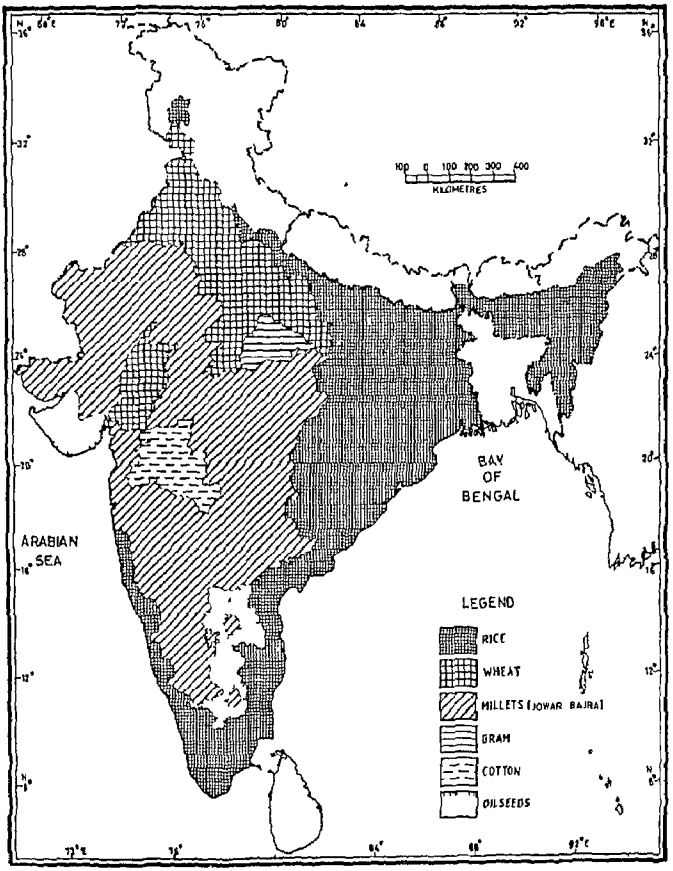
Empirical technique is largely based on the experience of the farmers and the observed facts Baker was the first geographer who adopted the empirical technique and demarcated the agricultural belts of USA. The Cotton Belt, the Corn Belt, and the Wheat Belt of USA were demarcated on the basis of observed data. The areas in which corn was having the dominance were marked as Corn Belt. This technique gives a generalized picture of the cropping pattern and has the tendency of overgeneralization. By adopting the empirical technique, Jonasson, Jones, Taylor, Valkenberg and Cressay demarcated the agricultural regions of the different parts of the earth. The technique has, however, been criticized as it is less objective and relatively unscientific.

Single Element Technique

This is an arbitrary technique in which the single element of agricultural landscape is taken into consideration. In this technique the relative position of different agricultural enterprises is taken into consideration. The demarcation of rice, wheat and *bajra* regions of India on the basis of first ranking crops is an illustration of this technique (Fig. 7.1). The main weakness of this technique is that it conceals the position and importance of other crops grown in the region. In other words, it leads to overgeneralization. The demarcation of Punjab as a wheat region and western Uttar Pradesh as sugarcane belt conceals the importance of rice and other cash crops which are also grown in

Figure 7.1

India First Ranking Crops 1990 94



these areas. Thus, this technique describes the agricultural situation inadequately as crops are generally not grown in isolation. A combinational analysis of crops is more important than the single crop/enterprise regions.

Multi-element or Statistical Technique

The multi-element technique is an improvement over the empirical and single element techniques of agricultural regionalization. In the statistical technique combinations of the closely associated features are taken into consideration. The crop combination and livestock regions as demarcated by Weaver, Doi and Coppock are the examples of this methodology. The main advantage of multi-element technique is that it is free from biasness and does not conceal the various agricultural phenomena which may be significant in the decision making process of the farmers. In the absence of reliable data this technique may not depict the ground reality of agricultural landscape of a region.

In the developing countries, there is paucity of reliable agricultural data. Consequently, agricultural regions delineated with the help of unauthentic data are bound to lead to faulty results. The non-availability of reliable data, however, is not a weakness of the multi-element technique. In fact, better results and judicious agricultural regions have been demarcated with the help of this technique in the developed countries of the world.

Quantitative-cum-Qualitative Technique

For the demarcation of agricultural regions, when the physical (terrain, slope, temperature, rainfall, soil, etc.), social (land tenancy, size of holdings and fields, religion, customs, etc.) and economic factors (capital investment, marketing, storage, etc.) are taken into consideration, such a technique is known as a quantitative-cum-qualitative technique of agricultural regionalization. An agricultural region, generally, is an area having homogeneity of crops and livestock. This technique has been applied by Baker (1926), Whittlesey (1936) and Carol (1952). The 14 main factors which should be taken into consideration for the demarcation of agricultural regions include six physical, viz., relief, climate, water, soil, subsoil and natural vegetation; two cultural, viz.,cultural vegetation and cultural structures; and six

functional, viz, rural population, cultural and technological stage, farming operation, organization for providing the rural population with economic and cultural goods, and commerce.

The non-availability of reliable data on the various facets of agriculture over the greater parts of the earth is the major constraint in the application of multifacet technique for agricultural regionalization Despite several limitations the qualitative-cum-qualitative technique has been adopted by geographers for the delimitation of agricultural regions at the macro, meso and micro levels.

The agricultural geographers have, however, could not develop a technique of agricultural regionalization which may be universally accepted and which may help in understanding the agriculturel at the local, regional, national and international levels

Methodology for Agricultural Regionalization

As discussed at the outset, regionalization is the process of dividing an area into territorial units of uniformities and is the result of a set of processes The main advantage of agricultural regionalization lies in the fact that it helps in the formulation of agricultural plans which may go a long way in reducing the regional disparities and inequalities.

The agricultural regionalization may be done with the help of following methods.

1. Cropping patterns.
2. Crop combination, concentration and diversification patterns.
3. Regional patterns of agricultural productivity
4. Degree of commercialization.
5. Patterns of crop rotation

Cropping Patterns

Cropping pattern means the proportion of area under various crops at a point of time. The crop statistics published by the governments are used to denote the cropping patterns Cropping pattern is, however, a dynamic concept as it changes over space and time The cropping patterns of a region are closely influenced by the geoclimatic, so-

ciocultural, economic, historical and political factors.

As discussed in Chapter 3, the physical environment (physiography, climate, soils and water) imposes limits on the growth and distribution of plants and animals. The role of man in the cultivation of certain crops in a region is also quite important. Man, by his technological advancement, can ameliorate the physical limits. The cultivation of rice in Punjab, Haryana and Rajasthan (Ganganagar) testifies this fact. Nevertheless, in different parts of the world, the physical environment reduces the choice of crops, either by prohibiting the growth of certain plants or by reducing their yield per unit area.

Depending on the terrain, topography, slope, temperature, amount and reliability of rainfall, soils and availability of water for irrigation, the cropping patterns vary from region to region. The perception and assessment of environment also guide to grow certain crops in a region. Those areas of the world where physical diversities are less, the cropping patterns are less diversified. For example, in the rainfall deficient areas of Rajasthan (India), the farmers grow *bajra* (bulrush millet), while in the Brahmaputra valley of Assam rice is the dominant crop. Similarly, cotton is grown in the *regur* (black earth) soil of Maharashtra and Gujarat, while the loamy soils of western Uttar Pradesh, Haryana and Punjab are ideally suited for wheat, rice and sugarcane crops. Moreover, the land tenancy, ownership of land, size of holdings and size of fields also impose restrictions on the cropping patterns of a region. In the areas of small holdings, the farmers tend to be subsistent despite innovation diffusion. Contrary to this, the farmers with large holdings have more risk bearing capacity and they have relatively high degree of commercialization.

The cropping patterns of a region or areal unit may be determined on the basis of areal strength of individual crops. The first, second and third ranking crops of an areal unit may be called as the dominant crops of that unit. These crops, if occupying more or less the same percentage of the total cropped area, shall be competing for area with each other and the farmer will decide which crop may fetch him more profit in a given year under the prevailing rainfall and demand, supply and commodity price condition. In general, for the determination of cropping patterns of a region, the minor crops (crops occupying insignificant proportion of the total cropped area) are

eliminated.

Apart from the proportion of area under a particular crop, its relative yield also guides the suitability of that crop in a given geoclimatic and cultural setting. The relative yield index and the relative spread index for the determination of suitability of crop may be calculated by applying the following formulas.

$$\text{Relative Yield Index} = \frac{\text{Mean yield of the crop in a component areal unit}}{\text{Mean yield of the total area}} \times 100$$

$$\text{Relative Spread Index} = \frac{\text{Area of the crop expressed as percentage of the total cultivated area in the areal unit}}{\text{Area of the crop expressed as percentage of the total cultivated land in the entire region}}$$

On the basis of these indices the suitability of the crop grown in a region may be ascertained. If the relative yield is below 90 per cent, then it may be an inefficient crop and therefore should not be devoted more area to its cultivation.

The area under each crop in a given region may be classified under four categories :

high yield, high spread
high yield, low spread
low yield, high spread
low yield, low spread

On the availability of an alternative more efficient crop than the existing ones, new cropping patterns may emerge in a region. The cropping patterns may be intensified with the help of high yielding short duration varieties. Any cropping sequence to be adopted by the cultivators should be flexible. The suitability of a crop and cropping pattern may be judged on the basis of the following :

1. The crop should not accentuate certain diseases as a result of a fixed continuous rotation.
2. The crop should not exhaust on some specific plant nutrients from a particular depth of the soil.

3. The crop should be fertility building and soil improving.
4. The crop should fetch handsome return to the cultivator and should provide the farmer employment and income all the year round. Moreover, the crop should ensure the optimum utilization of his resources, particularly inputs like irrigation water, chemical fertilizers, insecticides, pesticides, equipments, power and family labour.

In greater parts of India, agriculture is still largely subsistent in character. Consequently, the foodgrain crops occupy over 71 per cent of the gross cropped area Among the cereals rice and wheat rank first and second respectively. Cotton, sugarcane and oilseeds are the major cash crops. Among the pulses, gram, lentil, black gram, green gram, pegion pea are important. The subsistent cropping patterns of India are based on utilization of the inherent fertility of the soil without the much use of modern inputs and technology. The areas in which HYV have been diffused successfully under the Green Revolution are, however, exceptions.

The importance of adoption of suitable cropping patterns in a developing country like India cannot be overemphasized. The horizontal expansion of agriculture is not possible without heavy capital investments. Only judicious utilization of land by adopting more remunerative cropping patterns, scientific rotation of crops and multiple cropping may help in overcoming the food and raw material problems of the country. The change in the cropping pattern and introduction of crops which enhance the soil fertility are imperative to make agriculture more remunerative and sustainable.

Crop Concentration

Crop concentration means the variations in the density of any crop in an area/region at a given point of time The concentration of a crop in an area largely depends on its terrain, temperature, moisture and pedological conditions Each crop has a maximum, minimum and optimum temperature. It has a tendency to have high concentration in the areas of ideal agroclimatic conditions and the density declines as the geographical conditions become less conducive. It is because of the suitability of agroclimatic conditions that cotton has high concentra-

tion in the black earth (*regur*) region, wheat dominates in Punjab and Haryana, *bajra* in Rajasthan and rice is the leading crop in Assam, West Bengal, Orissa, coastal Andhra Pradesh, Tamil Nadu and Kerala. Delineation of crop concentration region helps in ascertaining the areas where a particular crop grows well even with the help of *minimum inputs, and thus has great significance for agricultural development and planning.*

A number of statistical techniques have been evolved and applied for the demarcation of crop concentration regions. The percentage share of a crop in the total cropped area and the determination of relative density with the help of location quotient are some of the techniques that are frequently used for the demarcation of crop concentration regions. The Department of Agriculture, Government of India has adopted the following technique for the determination of crop concentration at the local, regional and national levels:

$$\text{Cropping Intensity} = \frac{\Sigma a_{ij}}{\Sigma a_{io}} \Big/ \frac{N_j}{N_0} \times 100$$

where

a_{ij} = area under the ith crop in the jth year.

a_{io} = area under the ith crop in the base year.

N_j = net area sown in the jth year.

N_0 = net area sown in the base year.

Location Quotient Method of Crop Concentration

The location quotient technique has also been applied by geographers for the determination of regional character of cropping patterns. In this technique the regional character of crop distribution is investigated and determined, first by comparing the proportion of sown area under different crops and ranking them, and secondly, by relating the crop density in each of the component areal units of the region/country to the corresponding density of the region/country as a whole. This approach makes it possible to measure the regional concentration of the crops objectively. It also helps to identify and differentiate areas that have some significance with regard to the crop distribution within the region.

The location quotient method may be expressed as under :

$$\text{Index for the determination of crop concentration} = \frac{\text{Area of x crop in the component areal unit}}{\text{Area of all crops in the component areal unit}} - \frac{\text{Area of x crop in the entire region/country}}{\text{Area of all crops in the entire region/country}}$$

By applying the above technique, if the index value is greater than unity, the component areal unit accounts for a share greater than it would have had if the distribution were uniform in the entire region, and therefore, the areal unit has a concentration of great agricultural significance. After ascertaining the index values for the crops in the component areal units, they are arranged in an ascending or descending order. The index scale is calculated by dividing the array into equal parts to distinguish the very high, high, medium, low and very low concentrations. In general, higher the crop concentration index, higher is the level of interest in the production of that crop.

The main advantage of the location quotient technique for the delineation of crop concentration lies in the fact that it enables the geographers and planners to understand the areas of specialization of different crops grown in a region at a given point of time. The continuous cultivation of a particular crop in a unit or region, however, leads to progressive reduction in yield. This depletion of soil happens because the crop exhausts certain nutrients from the soil. Consequently, the natural fertility of the soil steadily declines. Rotation of crops with diverse choice, permissible under the given environmental conditions, therefore, needs to be adopted to maintain the fertility of the soil. A scientific rotation of crops not only makes agriculture a more remunerative occupation, but it also makes the agro-ecosystem more resilient and sustainable.

Crop Combination Regions

J. C. Weaver

The study of crop combination regions constitute an important aspect of agricultural geography as it provides a good basis for agricultural regionalization. The crops are generally grown in combinations and it is rarely that a particular crop occupies a position of total isolation other crops in a given areal unit at a given point of time. The distribution maps of individual crops are interesting and useful for planners, but it is even more important to view the integrated assemblage of

the various crops grown in an areal unit. For example, the demarcation of India into the rice region or wheat region does not explain the agriculturally significant fact that very often the wheat region also has a rice crop and vice versa, or wheat is often grown with gram, barley, mustard, lentil, peas and rapeseed. For a comprehensive and clear understanding of the agricultural mosaic of an agroclimatic region and for the planning and development of its agriculture, a systematic study of crop combinations is of great significance.

In recent years the concept of crop combination has engaged the attention of geographers and agricultural land use planners. The studies made so far in this field range in approach from topical to regional and vary in extent from small areas of minor political units to the entire country.

The different methods applied in the delineation of crop combination regions can be summed up under two headings:

(i) The first method for the demarcation of crop combination regions is the arbitrary choice method, e.g., the first crop only, the first two crops only or the first three crops, etc. The crop combinations delineated on arbitrary choice method are, however, not rational and objective as by applying arbitration the rest of the crops grown in the area are irrationally excluded without any consideration of their percentage weightage in the total cropped area.

(ii) The second method is developed in terms of variables based on certain differences which are relative and not absolute. This method being based on statistical approach is more accurate, reliable and scientific as it gives better objective grouping of crops of a region. *The statistical techniques about crop combination have been* modified suitably by the geographers from time to time. The arbitrary choice method and some of the quantitative techniques used in the delineations of crop combinations have been illustrated by taking the state of Uttar Pradesh as the area of study.

In Uttar Pradesh, the cultivation of crops is the dominant economic activity. Of the total reporting area of about 29.6 million hectares, some 17 4 million hectares represent the net sown area, i.e., about 60 per cent as compared to 47 per cent for the whole of India. In order of area covered, the most important crops are rice, wheat, gram, sugarcane, barley, maize, *bajra* and *jowar*. These crops occupy

about 96 per cent of the net cropped area but because of double cropping their total area actually represents 80 per cent of the gross cropped area. Crops occupying less than one per cent of the gross cultivated area have not been included as they occupy an insignificant area. The agricultural statistics relate to the district unit and are the averages of five years (1990-95).

As described earlier, the first or first two or first three crops, occupying the major area of the gross cropped land, are selected on the basis of their areal strength, i.e., area occupied by each one of them in a given year.

First Crop Only

In this method, the first ranking crop, i.e., the crop occupying the highest percentage of the total cropped area in each of the component areal units could be chosen, no matter what percentage it occupies in the gross cropped area. With the help of this method, the distributional pattern of first ranking crops has been plotted in Figure 7.2. The districts occupied by the first ranking crops are given in Table 7.1 and they are arranged in alphabetical order and not in decreasing order of percentage area occupied by them.

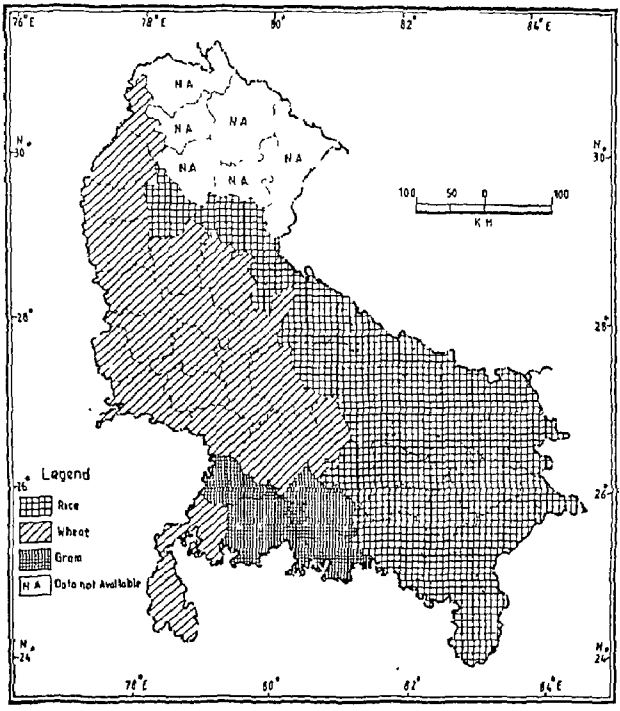
Table 7.1

Uttar Pradesh : First Ranking Crops(1991-92)

Crop	*No. of Districts*	*Names of the Districts*
Rice	28	Agra, Allahabad, Azamgarh, Bahraich, Ballia, Barabanki, Basti, Bijnor, Dehra Dun, Deoria, Faizabad, Ghazipur, Gonda, Gorakhpur, Jaunpur, Kheri, Lakhimpur, Maharajganj, Mau, Mirzapur, Nainital, Pratapgarh, Pilibhit, Rai Bareli, Sitapur, Sonbhadra, Sultanpur, Varanasi
Wheat	26	Aligarh, Bareilly, Budaun, Bulandshahr, Dehradun, Etah, Etawah, Farrukhabad, Firozabad, Ghaziabad, Hardoi, Hardwar, Jhansi, Kanpur, Lalitpur, Lucknow, Mathura, Mainpuri, Meerut, Moradabad, Muzaffarnagar, Rampur, Saharanpur, Shahjahanpur, Sidhartnagar, Unnao
Gram	4	Banda, Fatehpur, Jalaun, Hamirpur

It may be noticed from Table 7.1 that rice and wheat, ranking first in 28 and 26 districts respectively, are the leading crops in Uttar Pradesh. These crops divide the state into rice and wheat regions, the

Figure 7.2
Uttar Pradesh First Crop Only, 1991-94



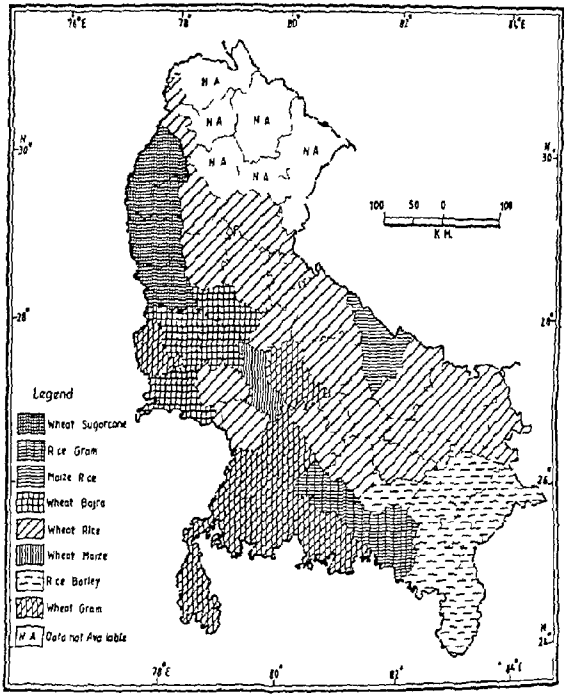
former dominating in the north and eastern districts and the latter in the south and western districts of Uttar Pradesh (Fig. 7.2). Gram ranks first in Banda, Fatehpur, Jalaun and Hamirpur. In Uttar Pradesh, where monoculture is not prevalent and farmers generally diversify their cropping patterns, there is no merit in adopting this method for the delineation of crop combinations as it helps in ascertaining the areas of dominance of the first ranking crops.

First Two Crops

On the basis of first and second ranking crops, nine crop combinations may be recognized in Uttar Pradesh. The result and crop combi-

Figure 7.3

Uttar Pradesh First Two Crops, 1991-94



nations have been plotted in Figure 7 3

The districts occupied by these crops are given in Table 7 2 It reveals that in 26 out of the 55 crop reporting districts of Uttar Pradesh, rice and wheat enter into crop combination while in the remaining districts except Agra, the presence of rice or wheat is quite significant in all the combinations Gram, barley, maize, *bajra* and sugarcane are the other crops that constitute the crop combinations

The delineation of crop combination regions on the basis of first two crops is irrational as there are 12 districts in the state in which the accumulated percentage of the first two crops is even less than 50 per cent of the gross cropped area The relative strength of the first

two crops in these 12 districts is Etawah 40 per cent, Mainpuri and Rampur 41 per cent each, Bulandshahr and Shahjahanpur 46 per cent each and Unnao and Lakhimpur 47 and 49 per cent respectively

Table 7 2

Uttar Pradesh First Two Crops Combination(1991-92)

Crop	*No of Districts*	*Names of the Districts*
Rice/wheat	26	Bareilly Basti Bijnor Dehradun Deoria Etawah Faizabad Firozabad Gonda, Gorakhpur Hardwar Lakhimpur Lucknow Maharajganj Mau Mainpuri Moradabad Nainital Pilibhit Rai Bareli Rampur Sahajahanpur Sitapur Sonbhadra Sultanpur Unnao
Rice/barley	7	Azamgarh Ballia, Ghazipur Jaunpur Mirzapur Pratapgarh Varanasi
Wheat/gram	7	Banda Hamirpur Hardoi Jalaun Jhansi Kanpur Mathura
Wheat/sugarcane	5	Bulandshahr Ghaziabad Meerut Muzaffarnagar Saharanpur
Rice/gram	3	Allahabad Barabanki Fatehpur
Wheat/*bajra*	4	Aligarh Budaun Etah Sidhartnagar
Wheat/maize	1	Farrukhabad
Rice/maize	1	Bahraich
Gram/*bajra*	1	Agra

First Three Crops

When the first three crops were taken into consideration, the number of crop combination regions become as large as eleven These crop regions have been plotted in Figure 7 4

The districts occupied by these crops are given in Table 7 3 which shows that rice and wheat are the dominating constituents in the first three ranking crop combinations, which cover 32 out of the 55 reporting districts Other crops entering the combinations are sugarcane, barley, gram, maize and *jowar* The method of first three crops is also unscientific and irrational, as by doing so the rest of the crops are excluded without any consideration of their areal strength Looking at the weaknesses of the arbitrary choice method, it is necessary to apply some standard statistical techniques for a more objective grouping of crops Some of the quantitative techniques used for the grouping of crops have been discussed in the following paras

Figure 7.4

Uttar Pradesh First Three Crops 1991-94

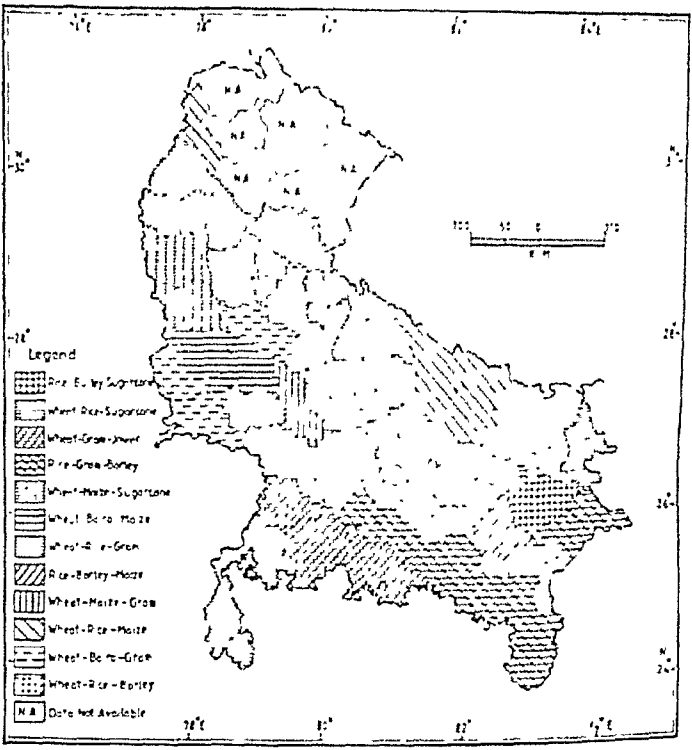


Table 7.3

Uttar Pradesh : First Three Crop Combination(1991-92)

Crop	*No of Districts*	*Names of the Districts*
Wheat/rice/ gram	13	Barabanki, Bareilly, Etawah Faizabad Firozabad Hardoi, Jhansi, Kanpur, Lucknow, Mainpuri, Shahjahanpur, Sitapur, Sultanpur
Wheat/rice/ sugarcane	15	Azamgarh, Bijnor, Deoria Hardwar, Ghaziabad, Lakhimpur, Mau Maharajganj, Moradabad, Muzaffarnagar Nainital, Pilibhit Rampur, Saharanpur, Sonbhadra

Contd

Contd

Wheat/rice/barley	6	Basti Gorakhpur Pratapgarh Unnao Rai Bareli Varanasi
Rice/gram/barley	5	Allahabad Ballia, Fatehpur Ghazipur, Mirzapur
Wheat/gram/*jowar*	3	Banda Hamirpur Jalaun
Wheat/rice/maize	3	Bahraich Dehradun Gonda
Wheat/gram/*bajra*	4	Agra Budaun Mathura Sidhartnagar
WheAt/maize/sugarcane	2	Bulandshahr Meerut
Wheat/*bajra*/maize	2	Aligarh Etah
Wheat/maize/ gram	1	Farrukhabad
Rice/barley/maize	1	Jaunpur

Statistical Regional Analysis

At present, there is explosion of data Statistics and information are being collected at the micro and the household levels in all the developed and the developing countries For any scheme of regionalization such data are of immense importance The invention of computers has made possible the processing of huge and complex data that would have been impracticable without its aid With the help of sophisticated computer devices it has become possible to do advance statistical analysis of the data relating to different variables to demarcate the patterns of complex mosaic distribution The use of computer for the processing of data is a time saving device which gives reliable results In the field of agricultural geography Weaver (1954) was the first to use statistical technique to establish the crop combination of the Middle West (USA)

In his attempt for the delineation of agricultural regions of the Middle West in the United States, Weaver based his analysis on acreage statistics Weaver computed the percentage of total harvested cropland occupied by each crop that held as much as 1 per cent of the total cultivated land in each of the 1081 counties covered in his work Excluding a few counties like Houston and Minnesota in which the crop combination was easy to ascertain, other counties showed a complex and confused picture of the percentage, occupied by different crops It was, therefore, necessary to devise "a rigorous approach that would provide objective constant and precisely repeatable procedure and would yield comparable results for different years and localities" In his work Weaver calculated deviation of the real per-

centages of crops (occupying over 1 per cent of the cropped area) for all the possible combinations in the component areal units against a theoretical standard. The theoretical curve for the standard measurement was employed as follows :

Monoculture	=	100 per cent of the total harvested crop land in one crop
2-crop combination	=	50 per cent in each of two crops
3-crop combination	=	33 3 per cent in each of three crops.
4-crop combination	=	25 per cent in each of four crops
5-crop combination	=	20 per cent in each of five crops
10-crop combination	=	10 per cent in each of 10 crops

For the determination of the minimum deviation the standard deviation method was used:

$$SD = \sqrt{\frac{\Sigma d^2}{n}}$$

where d is the difference between the actual crop percentages in a given county (areal unit) and the appropriate percentage in the theoretical curve and n is the number of crops in a given combination.

As Weaver pointed out, the relative, not absolute value being significant, square roots were not extracted so, the actual formula used was as follows :

$$d = \frac{\Sigma d^2}{n}$$

To illustrate the Weaver's technique an illustration can be given from Gorakhpur district in which the percentage share of crops in the cropped area in a year was as follows : rice 48 per cent, wheat 23 per cent, barley 15 per cent, sugarcane 6 per cent, and gram 5 per cent.

Monoculture

$$= \frac{(100-48)^2}{1} = 2704$$

2-crop combination

$$= \frac{(50-48)^2 + (50-23)^{2)}}{2} = 366.5$$

3-crop combination

$$= \frac{(33\ 3-48)^2 + (33.3-23)^{2)} + (33.3-15)^2}{3} = 216$$

4-crop combination

$$= \frac{(25-48)^2 + (25-23)^{2)} + (25-15)^2 + (25-6)^2}{4} = 248$$

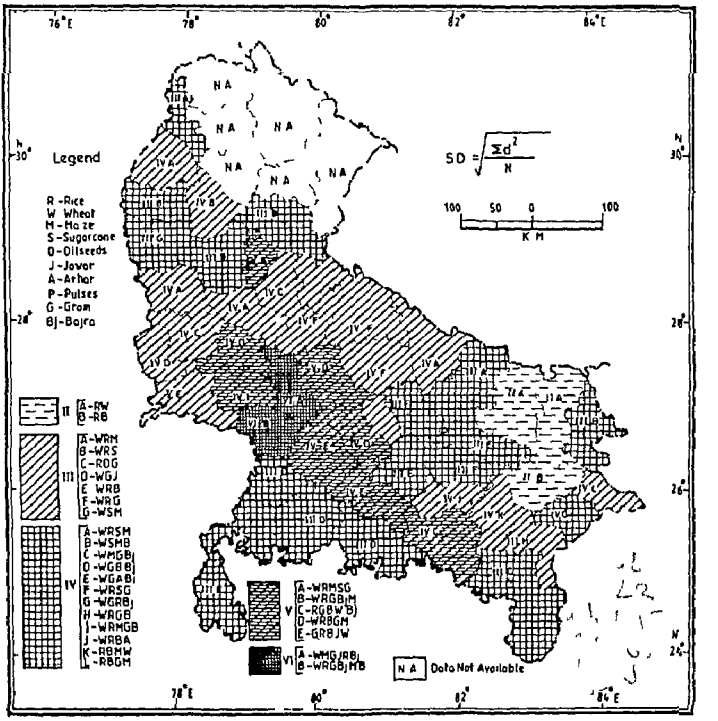
5-crop combination

$$= \frac{(20-48)^2 + (20-23)^{2)} + (20-15)^2 + (20-6)^2 + (20-5)^2}{5} = 248$$

The deviation of the actual percentages from the theoretical

Figure 7.5

Uttar Pradesh Crop Combination Regions, 1991-94
(Standard Deviation Method)



curve is seen to be the lowest for a 3-crop combination. This result established the identity and the number of crops in the basic combination for the district as RWB (rice-wheat-barley).

The resultant cropping patterns plotted in Figure 7.5 are contiguous crop combination regions. The problem of small areas of crop combination was solved by adding a symbol, e.g., IIIA(wheat-rice-maize), III-B (wheat-rice-*bajra*) and so on. The application of Weaver's method gave 10 crop combination regions to Uttar Pradesh. The districts falling into different crop associations are given in Table 7.4.

Table 7.4

Uttar Pradesh · Weaver's Method—Crop Combination

No. of Crops	*No of Districts*	*Name of Districts*
Monoculture	-	-
2	1	Jhansi
3	9	Agra, Bahraich, Bijnor, Dehra-Dun, Gorakhpur, Hamirpur, Muzaffarnagar, Nainital, Sonbhadra
4	6	Bareilly, Deoria, Hardwar, Lakhimpur, Pilibhit, Saharanpur
5	12	Banda, Fatehpur, Firozabad, Ghaziabad, Maharajganj, Manipuri, Mau, Meerut, Moradabad, Rampur, Sitapur
6	12	Aligarh, Allahabad, Ballia, Bulandshahr, Etah, Gonda, Harodi, Mathura, Pratapgarh, Rae Bareli, Sidhartnagar, Unnao
7	6	Barabanki, Basti, Budaun, Faizabad, Farrukhabad, Sultanpur
8	6	Azamgarh, Ghazipur, Jalaun, Kanpur, Lucknow, Varanasi
9	1	Etawah
10	1	Mirzapur

Weaver's method has admirably been accepted and applied for the demarcation of crop combination and agricultural regionalization as its application results into suitable and accurate grouping of crops. The technique, however, gives most unwieldy combinations for the units of high crop diversification. Such a problem of generalized crop combination was met in 12 districts of Uttar Pradesh. In four, out of them, the decrease in the variance was gradual (Table 7.5) where every crop occupying as much as 1 per cent of the gross harvested

area was included in the combination to produce the lowest variance

Table 7.5

Weaver's Method Variance Values

Crop Combination	*Azamgarh*	*Mirzapur*	*Ghazipur*	*Varanasi*
Monoculture	3136	3481	3600	3249
2-crop combination	383	648	501	672
3-crop combination	296	253	206	292
4-crop combination	263	155	179	201
5-crop combination	236	149	159	186
6-crop combination	210	139	148	163
7-crop combination	194	137	140	153
8-crop combination	185	133	131	141
9-crop combination	180	130	-	-
10-crop combination	-	120	-	-

In the remaining eight districts (Sultanpur, Shahjahanpur, Sonbhadra, Sidhartnagar, Faizabad, Etawah, Barabanki and Kanpur), the value of variance does not show gradual decline In these districts the variance decreases up to a few places from where it increases and then decreases again so as to surpass even the former decrease

Table 7.6

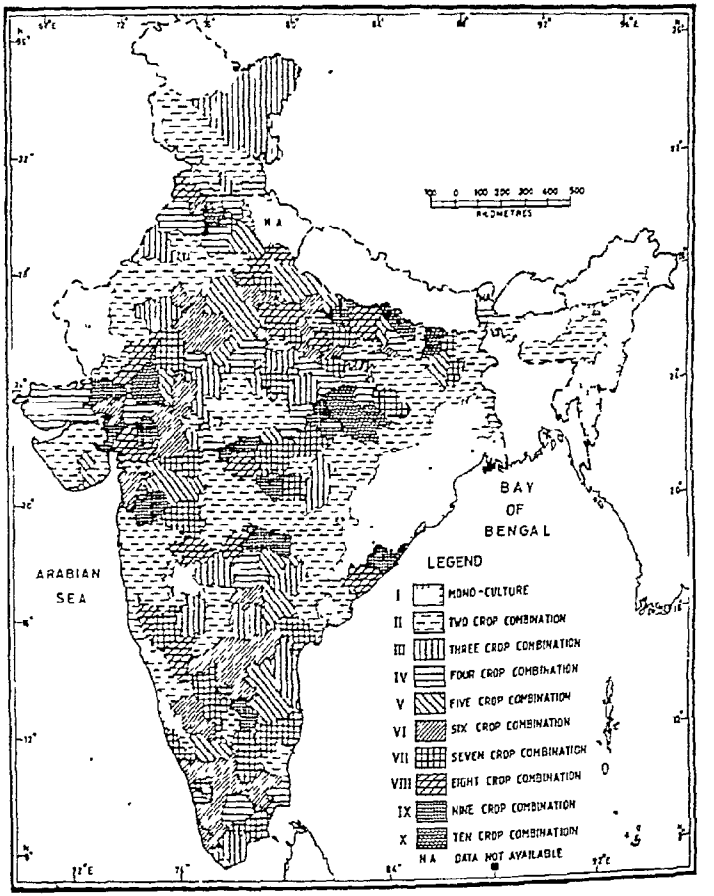
Sultanpur and Shahjahanpur Crop Variance

Crop Combination	*Sultanpur*	*Shahjahanpur*
Monoculture	3025	5329
2-crop combination	590	245
3-crop combination	253	67
4-crop combination	187	74
5-crop combination	190	72
6-crop combination	122	66
7-crop combination	60	-

Table 7 6 makes the point more clear. It reveals that the variance in Sultanpur decreases to 187 in the 4-crop combination and later on

Figure 7.6

India—Crop Combination Regions, 1961-64



rises to 190 in 5-crop combination and, therefrom, decreases continuously so that after crossing the value of the former low, attains the lowest variance, i.e., 60 in 7-crop combination. Similarly, in Shahjahanpur, the variance decreases to 67 in 3-crop combination, but it increases in 4-crop combination being 74 and then decrease to 66 in 6-crop combination. It has also been observed that the technique of least deviation or minimum standard deviation from the abstract theoretical combination value fails to operate in the enumeration units where the actual regional share of crops is quite close to one another. In addition to the problem of generalization in crop combination, in the areal units of high specialization, Weaver's method also suffers from the setback of laborious calculations. In the process of calculation, any mistake in arithmetic, except the gross one, may not be easily detected. Weavers technique when applied at the district level for the period of 1961-64 gives ten crop combinations to India which have been plotted in Fig. 7.6.

Out of the many approaches to combinational study, Weaver's method used in crop combination has been applied largely by geographers. Some have followed this method in demarcating crop and livestock combinations (Scott, 1957; Bennett, 1961; Coppock, 1964) or industry combinations (Johnson and Teufner, 1968). Others have shown its weakness (Rafiullah,1956; Hoag, 1969) or have tried to present and use it after suitable modifications (Doi, 1959, 1970, Thomas, 1963; Ahmad and Siddiqui, 1967; Husain, 1976; Jasbir Singh, 1977).

Weaver's method as modified by Doi when applied by Siddiqui in the *Deficiency Disease Combinations in Uttar Pradesh* (1972) gave more realistic results which can be obtained with the help of a table of critical values in a short time. Scott made modifications in the Weaver's method and the modified technique was applied to a survey of both crop and livestock combinations in Tasmania. Modifications were made to make the procedure even more objective, constant and precisely repeatable, one being to include speciality crops in the statistical definition, and Scott's aim was to employ the results to help agcicultural regions. He noted that "... a study of the crop and livestock pattern in Tasmania reveals that both the grouped combinations and the ranked combinations are relevant, since it is the ranked

combinations rather than the grouped combinations which define the major crop regions and the grouped rather than the ranked combinations which define the livestock region. This stems from the fact that crop associations are by no means so strong in Tasmania as livestock association".

Coppock (1964), using a modified version of Weaver's method, produced not only crop and livestock combinations, but also combinations of enterprises in England and Wales. Coppock took into account rank in recognizing the leading crops. His objective was not merely to plot the combinations of crops and livestock separately but the grouping together of these as to reveal distribution of types of farm enterprise which usually include both crops and livestock on one farm. This includes comparison of unequal units. e.g., livestock with crops and potatoes and grains. For equating the different unequal unit Coppock took into account the feed requirements Livestock units with slightly varying equivalent are widely used today in calculations of food requirements and farming intensity.

The Weaver's technique was subsequently modified by Doi (1959). Doi's technique used to be considered to be the easiest for combination analysis prior to the application of computer programming facilities. The Doi's formula may be expressed as :

$$(\Sigma d^2)$$

The combination having the lowest (Σd^2) will be the crop combination. In Doi's technique, it is not required to calculate (Σd^2) for each combination but the crop combination is actually established by One Sheet Table (Table 7.7), which represents critical values for various elements at different ranks against cumulative percentage of elements at higher ranks; for an agricultural geographer elements are main crops, livestock. or enterprises. The use of One Sheet Table requires only the summing up of actual percentages under different crops instead of finding the differences between actual percentages and theoretical distributions. Table 7 7 is an abridged format of One Sheet Table prepared by Doi in 1957.

Table 7.7

An Abridged Part of Deviation Analysis Table (One-Sheet Table)

	Rank of Element												
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
	Critical Value												
Cumulative percentage of higher ranking elements	95										6 98	6 27	5 68
	90							8 84	7 60	6 67	5 94	5 35	4 49
	85				12 93	10 00	8 17	6 91	5 99	5 29	4 73	4 29	3 91
	80			13 83	10 00	7 85	6 46	5 49	4 78	4 23	3 79	3 33	3 14
	75		16 67	10 57	7 75	6 13	5 06	4 32	3 76	3 33	2 99	2 71	2 49
	70	27 64	12 25	7 93	5 96	4 65	3 85	3 29	2 87	2 55	2 29	2 08	1 90
	65	18 38	8 66	5 63	4 19	3 14	2 77	2 37	2 07	1 84	1 65	1 50	1 37
	60	11 27	5 46	3 59	2 68	2 14	1 78	1 52	1 33	1 18	1 06	0 97	0 88
	55	5 38	2 68	1 73	1 29	1 04	0 86	0 74	0 64	0 57	0 52	0 47	0 43
	50	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00

Source Doi, Kikukazu, "The Industrial Sturcture of Japan Prefectures", Tokyo, *Proceedings of the International Geographical Union*, Regional Conference in Japan, 1957, pp 310-316

The use of Doi's One Sheet Table can be seen by making use of actual percentages under different crops in the Saharanpur district for the year 1991-92. The ranked and cumulative percentages are as shown in Table 7.8.

Table 7.8

Cropping pattern in Saharanpur District (1991-92)

Ranking	*Crop*	*Percentage of Total Cropped Area*	*Cumulative Percentage*
1	Wheat	43 00	-
2	Rice	23 00	66 00
3	Sugarcane	14 00	80 50
4	Maize	5 00	85 50
5	Fodder	4 00	89 50
6	Pulses	4 00	93 50
7	Oilseeds	3 00	96 50
8	Barley	1 50	98 00
9	Potato	1 00	99 00
10	Others	1 00	100 00

According to Doi's technique all those crops are included in the combination whose cumulative percentage is less than 50, or the critical value for all the crops at different ranks against 50 in zero Therefore, the scale of cumulative percentage starts from above 50 per cent which is contributed by the higher ranks, may be the first one, two or three crops, and so on In the district of Saharanpur, the first crop (wheat) occupies 43 per cent, the next is automatically included so as to make the cumulative percentage above 50 per cent The next crop, rice, is included in the combination which makes the sum of the first two crops 66 per cent (Table 7 8)

One Sheet Table (Table 7 7) of critical values for different ranks of crops after the first two ranks is to be consulted as follows

1 Cumulative percentage of 66 (wheat and rice) lies between 65 and 70 It is close to 65, select 65 as the sum of percentage of the higher ranking elements, i e , wheat and rice, contributing to over 50 per cent of the total cropped area
2 Now under the heading 65. the critical value for the third rank of element is lower than the third crop, i e , sugarcane, occupying 14 per cent, or actual percentage of third crop in larger than critical value, i e , 8 66, and therefore, it is to be included in the combination The cumulative percentage of three elements (crops) comes to 80 5 (Table 7 7)
3 The cumulative percentage of 80 50 lies between 80 to 85, but it is close to 80 where the corresponding critical value of element (crop) at fourth rank is 13 83 As the crop at rank four occupies only 5 per cent, i e , lesser than the critical value, it is to be excluded from the combination

Thus, the Saharanpur district, according to the Doi's technique, has 3-crop combination, i e , wheat-rice-sugarcane (WRS) Doi's technique shows that higher ranking crops have high percentage, say above 10 per cent, the lower ranking crops with less than 5 per cent of the gross cropped area are usually excluded from the combination, and as such the fragmentary pattern of crop combination and the inclusion of minor crops in the combination are avoided This technique is most profitably applied to such a situation as is found in the

crops combination in which interrelationship exists between the component combination (Doi, 1957).

Maximum Positive Deviation Method

Looking at the inherent weakness of Weaver's method which tends to include all or most of the crops in the series by which the resultant combination become overgeneralized, Rafiullah (1956) developed a new deviation method in his work *A New Approach to the Functional Classification of Towns.* The technique devised by Rafiullah may be expressed as follows :

$$d = \sqrt{\frac{\Sigma D_p^2 - D_n^2}{N^2}}$$

where d is the deviation, D_p, is the positive difference and D_n, is the negative difference from the median value of the theoretical curve value of the combination, and N is the number of functions (crops) in the combination. Since it is the relative rank of the value of deviation which is needed, the under root sign may be ignored to save laborious calculations and the formula may be used in the following form :

$$d = \frac{\Sigma D_p^2 - D_n^2}{N^2}$$

To illustrate Rafiullah's maximum positive deviation method an illustration can be given from the Basti district of Uttar Pradesh, in which rice occupies 54 per cent, wheat 23 per cent, barley 9 per cent and sugarcane 5 per cent of the total cropped area.

$$\text{Monoculture} = \frac{(54-50)^2}{N^2} = \frac{(4)^2}{(1)^2} = 16$$

$$\text{2-crop combination} = \frac{(54-25)^2 - (23-25)^2}{N^2} = 209.25$$

3-crop combination =

$$\frac{(54-16.7)^2 + (23-16.7)^2 - (9-16.7)^2}{N^2} = 140.18$$

4- crop combination =

$$\frac{(54-12.5)^2 + (23-12.5)^2 - (9-12.5)^2 - (5-12.5)^2}{N^2} = 109.12$$

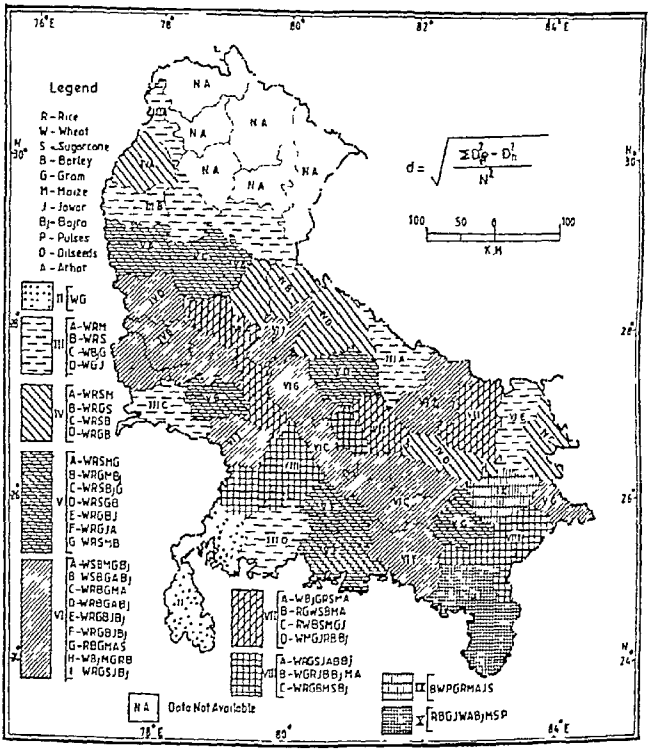
Since the variance of the 2-crop combination (209.25) is the maximum positive deviation, the district is designated with the 2-crop combination, i.e., rice and wheat (RW).

In the maximum positive deviation method, unlike the standard deviation method, the differences of actual values are calculated from the middle value of the theoretical standard and thus this method also gives the desired critical combination. An application of the maximum positive deviation method to the agricultural data of Uttar Pradesh results in the recognition of 6-crop combination. The combinations are mapped in Figure 7.7.

A comparison of Figure 7.5 and Figure 7.7 reveals that the later

Figure 7.7

Uttar Pradesh Crop Combination Regions, 1991-94
(Maximum Positive Deviation Method)



is identical in 16 districts, lower in 32 districts and higher in four districts In other words, the maximum positive deviation method includes lesser number of crops in combination and thus avoids the inclusion of insignificant crops from the combination

The statistical technique advocated by Raffiullah is more accurate, objective, and scientific, and therefore quite popular for the delineation of crop combination regions This technique has the capacity to handle the highly diversified cropping structures In general, the crop combinations demarcated on the basis of statistical techniques provide a sound base for agricultural planning and development

Crop Diversification

Crop diversification is a concept which is opposite to crop specialization The farmers all over the world, especially in the developing countries, try to grow several crops in their holdings in an agricultural year The level of crop diversification largely depends on the geoclimatic/socioeconomic conditions and technological development in a region In general, higher the level of agricultural technology, lesser the degree of diversification Moreover, the rich farmers prefer to specialize in agricultural enterprise while the poor and subsistent farmers are generally more interested in the diversification of crops The main causes for the crop diversification may be as under

(1) The uncertain weather, especially the erratic rainfall In the areas where the variability of rainfall is high and adequate sources of irrigation are not available, farmers grow several crops in a season, requiring different quantities of moisture It is being done mainly to get something from their fields even in the case of extreme weather (drought or deluge) conditions

(2) In the tradition bound subsistent farming systems the farmers grow several crops to meet the family requirements In such areas one may find a high degree of crops diversification

(3) Diversification has usually been done by the farmers to enhance nitrogen in the soil and to replenish the soil fertility It has been established by the agricultural scientists that crop specialization and monoculture for several years lead to soil

depletion In other words crop diversification increases the sustainability of arable land

(4) The diversification of crops also generates more employment as the farmers and agricultural workers remain busy in the sowing, weeding, harvesting and marketing of different crops throughout the year

(5) Diversification of crops also enables the farmers to provide a reasonable quantity of the costly inputs to their crops as different crops need different quantities of inputs (chemical fertilizers, insecticides, pesticides and irrigation) In the case of crop specialization the inputs are required at a specific time and many of the farmers may not be in a position to provide the required inputs at the appropriate time owing to their high cost

Looking at the importance of crop diversification many geographers have developed techniques for the measurement of crop diversification and crop specialization In general, it is assumed that if the number of crops grown in a component areal unit is large (say about 10), each crop occupying about 10 per cent of the cropped area, it would mean that the crop diversification is of a very high degree Contrary to this, if a crop occupies 100 per cent of the gross cropped area, the diversification is least and it will be a case of high degree of crop specialization

For the measurement of crop diversification, Bhatia (1965) developed a formula based on the gross cropped area The formula has been expressed as

$$\text{Index of Crop Diversification} = \frac{\text{Percent of sown area under } x \text{ crops}}{\text{Number of } x \text{ crops}} \times 100$$

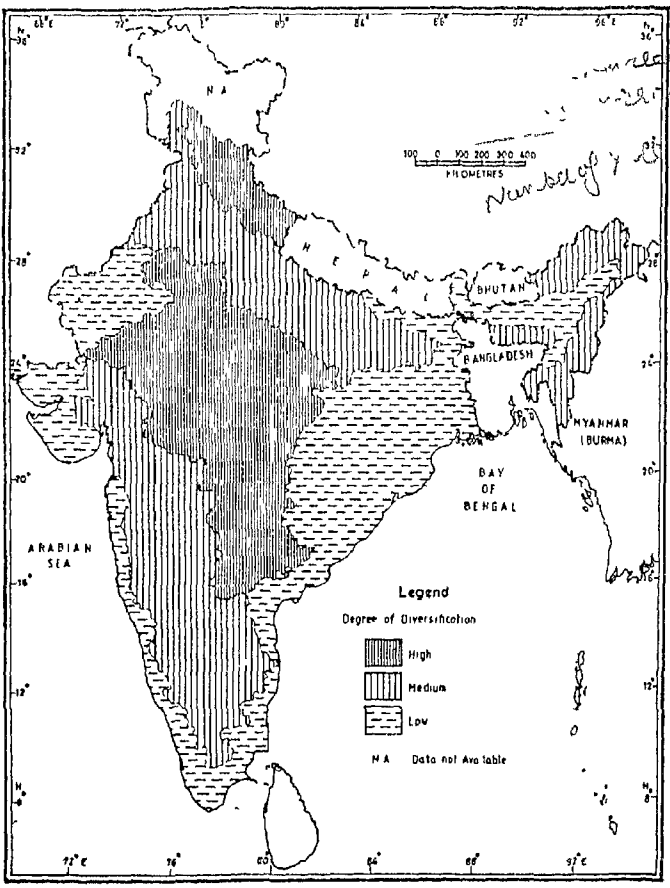
where x crops are those crops that individually occupy 10 per cent or more of the gross cropped area in the area under study

The main advantage of crop diversification is that it provides a relationship between the relative areal strength of the crops grown in a region The larger the number of crops having about 10 per cent of the gross cropped area, the higher is the crop diversification in the region In fact, it is an indicator of multiplication of agricultural activi-

ties which obviously involve intense competition among various activities for space The keener the competition, the higher the degree of diversification. and lesser the competition, greater will be the degree of specialization, or monoculture

Figure 7.8

India Crop Diversification 1991-94



The degree of crop diversification is closely influenced by the soil characteristics, soil moisture, amount of rainfall received, the availability of irrigation facilities, the accessibility of the arable land and the technology deployed by the cultivators As stated earlier, the areas of extreme wet or extreme dry climate are least conducive for crop diversification.

The crop diversification regions of India have been shown in Figure 7.8. It may be seen that Assam, West Bengal, northern Bihar, Orissa, eastern Madhya Pradesh, coastal Andhra Pradesh, southern parts of Tamil Nadu, Malabar and Konkan coasts, Kathiawad and western parts of Rajasthan have the lowest degree of crop diversification. In fact, these are the areas of monoculture, specializing either in rice or *bajra* cultivation. The greater parts of the Sutlej-Ganga plain, hill states of Northeast India, parts of Gujarat, Maharashtra, Karnataka, Andhra Pradesh, northwestern Tamil Nadu and southern parts of Jammu Division have moderate level of diversification, while the central parts of Madhya Pradesh, eastern Rajasthan, eastern Maharashtra and northern Andhra Pradesh have a high degree of crop diversification (Fig. 7.8).

The main advantage of a map showing the level of diversification lies in the fact that it helps in the future planning and development of agriculture. The regions which have a high degree of diversification are generally the areas of extreme moisture conditions and/or areas of erratic rainfall. In such areas agriculture is largely subsistent in character. The areas of high diversification of crops deserve special attention of planners for development of agriculture. A comprehensive plan for each of the regions of high diversification may go a long way in enhancing their agricultural productivity and in reducing the regional inequalities in agricultural development. There is increasing awareness among the experts of agriculture that crop diversification with suitable crop rotations is necessary for the maintenance of soil health and for making agriculture more productive and sustainable.

Agricultural Productivity

The measurement of production and inputs required for the production of that output is known as agricultural productivity. In other words, it is an input-output ratio. In traditional measurement of agri-

cultural productivity geographers and economists used to take into account the inputs like labour and capital and see them as costs which are incurred in the production of agricultural produce The traditional approach of measurement of agricultural productivity, however, does not take into account of social and environmental costs which are also incurred in the production of crops and raising livestock At present, in the measurement of agricultural productivity the question of sustainability of soil health of ecosystem and social acceptability have become increasingly important

Agricultural productivity of a micro or macro region is closely influenced by a number of physical (physiography, climate, soil. water), socioeconomic, political, institutional and organizational factors Thus, agricultural productivity is a function of interplay of physical and cultural variables and it manifests itself through per hectare productivity and the total production Agricultural productivity also depends on attitudes of the farmers towards work and their aspirations for better standard of living

The measurement of agricultural productivity helps in knowing the areas that are performing rather less efficiently in comparison to the neighbouring areas By delimiting the areas of low, medium and high productivity, agricultural plans may be formulated to remove and minimize the regional inequalities It also provides an opportunity to ascertain the ground reality, the real cause of agricultural backwardness of a tract/area or region

In the recent decades geographers and economists have developed sophisticated tools and techniques to determine the agricultural productivity Some of the well known techniques developed and used for the measurement of agricultural productivity and agricultural efficiency per unit area/per unit of time are given below

Output per unit area

Production per unit of farm labour

To assess agricultural production as grain equivalents (Buck 1967)

Input-output ratio (Khusro, 1964)

Ranking coefficient method (Kendall, 1939, Stamp, 1960, Shafi, 1990)

Carrying capacity of land in terms of population (Stamp, 1958).

Giving weight to the ranking order of the output per unit area with the percentage share under each crop (Sapre and Deshpande, 1964; Bhatia, 1967).

Determining an index of productivity (Enyedi, 1964; Shafi, 1972).

Computing the crop yield and concentration indices ranking coefficient (Jasbir Singh, 1976).

Involving the area, production and price of each cultivated crop in each of the constituent areal units of the region, and then relating the out-turn in terms of money of the unit to the corresponding productivity of the region (Husain, 1976)

To assess agricultural production in terms of money.

Assessing the net income in rupees per hectare of cropped area (Jasbir Singh, 1985).

Each of the techniques advocated and applied for the measurement of agricultural productivity suffers from one weakness or the other. The application of a technique may give satisfactory results at the micro or meso level but the same technique fails to deliver the goods at the national or global level. The input and output ratio technique seems to be a reasonably good one but the determination of inputs including environmental and social costs involved in the production is not an easy task The conversion of production of all crops in terms of money is also a useful technique but it is constrained by the prevailing prices of agricultural commodities which fluctuate from one areal unit to another and from one region to another.

A review of all the methodologies given above for the measurement of agricultural productivity is beyond the preview of this textbook. The Kendall's technique of ranking coefficient and the conversion of total production in terms of money have been illustrated in the following section.

Ranking Coefficient Method by Kendall

The ranking coefficient technique is quite simple and easy to apply. In this technique the component areal units are ranked according to

the per hectare yields of crops and the arithmetical average rank called the ranking coefficient for each unit is obtained. It is obvious that a component areal unit with relatively high yields will have low ranking coefficient, indicating a high agricultural productivity and vice versa. In other words, if a component areal unit was at the top of every list it would have a ranking coefficient of one and thus having the highest agricultural productivity and if it were at the bottom of every list, it would have a ranking coefficient equal to total number of units considered, showing the lowest agricultural productivity among the constituent units.

The ranking coefficient method can be illustrated with the help of an example. Suppose, in a region, there are 80 component areal units. In x component areal unit, on the basis of average yields, wheat ranks 5, rice 12, gram 20, cotton 21, barley 34, sugarcane 38, pulses 40 and mustard 54. The average rank, called the ranking coefficient of the areal unit x would be:

$$\text{Ag. Efficiency} = \frac{5+12+20+21+34+38+40+54}{8} = 28$$

The average ranked position of all the units of the region is thus calculated and then arranged in an ascending or descending array. The array is divided into five equal parts to obtain the very low, low, medium, high and very high agricultural productivity. With the help of the index scale the agricultural productivity of each unit can be ascertained and plotted on map. The technique was applied to determine the agricultural productivity of India and the agricultural statistics for the years 1990-95 were taken into consideration. The resultant patterns of productivity have been plotted in Figure 7.9.

Patterns of Agricultural Productivity

The patterns of agricultural productivity of India have been delineated with the help of Kendall's method. The ranking coefficient values of very high, high, medium, low and very low productivity have been given in Table 7.9, while the resultant patterns of productivity have been plotted in Figure 7.9.

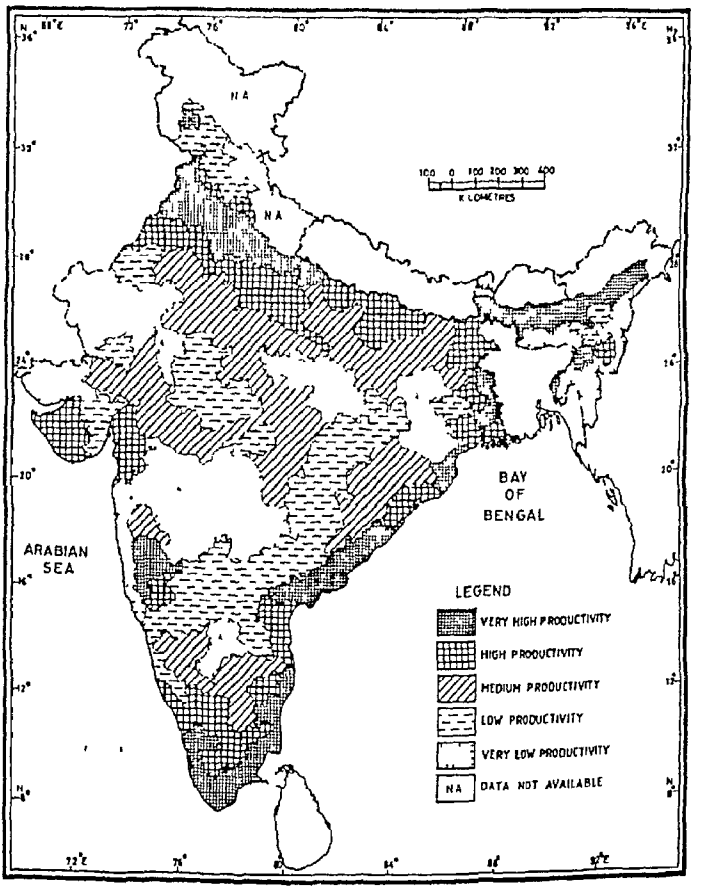
Table 7.9

India Agricultural Productivity Index (Kendall s Method)(1990-94)

Very High Productivity	< 75
High Productivity	< 90
Medium Productivity	< 105
Low Productivity	< 125
Very Low Productivity	> 125

Figure 7.9

India Agricultural Productivity 1990-94



Very High Agricultural Productivity

It may be observed from Figure 7 9 that the very high agricultural productivity is found in the upper parts of the Sutlej-Ganga plain, the Brahmaputra valley, the lower Gangetic plain, the coastal districts of Orissa, Andhra Pradesh, Tamil Nadu and Kerala, the valley of Kashmir, western part of Tripura, and the districts of Kolhapur and Sangli of Maharashtra Out of these a significant belt of high agricultural productivity stretches over the greater parts of Punjab, Haryana and the Meerut and Rohilkhand divisions of western Uttar Pradesh Wheat, rice, sugarcane and cotton are the dominant crops in this region It is interesting to note that over 90 per cent of the cultivated area in this tract is irrigated either by canals or tubewells or by both The farmers of this region are highly receptive to new agricultural innovations

In the Brahmaputra valley and in some of the districts of West Bengal and coastal Orissa rice and jute are the dominant crops The farmers grow two to three paddy crops in a year in their small holdings The annual floods during the rainy season are helpful in replenishing the soil fertility in the lower Ganga plain Very high agricultural productivity is also found in coastal Andhra Pradesh, the Kavery delta and the coastal parts of Tamil Nadu and Kerala Rice is the leading crop in this region where the farmers obtain two to three harvests of paddy in a year In Andhra Pradesh tobacco is an important cash crop In Sangli, Satara and Kolhapur districts of Maharashtra, sugarcane, wheat, onion, and grapes are abundantly grown In Anantnag, Pulwama and Baramulla districts of Kashmir, rice, orchards, apple and saffron are the major crops

High Agricultural Productivity

The areas of high agricultural productivity are generally found in the vicinity of the very high agricultural productivity regions, especially in the alluvial plains The districts in which the agricultural productivity is high are found in Punjab, Haryana, Uttar Pradesh, northern Bihar, West Bengal, the valley of Manipur, the Eastern Ghats and Kerala and Tamil Nadu Isolated patches of high agricultural productivity are also found in the districts of Jamnagar (Gujarat) and Ganganagar (Rajasthan) The dominant crops in these areas include

eat, rice, sugarcane, jute, cotton, oilseeds and maize.

dium Agricultural Productivity

dium agricultural productivity areas cover isolated tracts in the es of Uttar Pradesh, Bihar, Madhya Pradesh, Gujarat, Orissa and nil Nadu (Fig.7.9). In West Bengal, the districts of Bankura, bhum, and West Dinajpur have medium productivity, while in nil Nadu and Karnataka it is confined to the interior parts. Agriture in the areas of medium productivity is highly diversified and farmers are growing assorted crops, ranging from the high water uiring (paddy) to less water requiring (*bajra* millets) crops. The iculture of these areas is still subsistent and tradition bound. Nonilability of irrigation is the major barrier in the intensification and elopment of agriculture

v and Very Low Agricultural Productivity

e regional distribution of agricultural productivity shows that in greater parts of the central peninsular India, the productivity of d is low or very low. The districts of Chotanagpur (Bihar), Barmer l Jaisalmer (Rajasthan), Udhampur and Doda (J&K), Bhavanagar, rendernagar, Ahmadabad and Sabarkantha (Gujarat) have low to y low agricultural productivity.

For the delineation of agricultural productivity regions, the rank-, coefficient method is most simple and free from tiring calcula-ns. The resultant patterns of productivity also seem to be in conmity with the ground reality. Nevertheless, the technique of rank-, coefficient has the statistical weakness of ranking the crops. The tistical weakness lies in the fact that if in the three component al units, i.e., A, B, C, wheat occupies 60 per cent in A, 59 per cent B and 20 per cent in C of the total cropped area respectively; acding to the ranking coefficient method they will be ranked as 1, 2, ignoring the range difference in the percentage values. For exam-, B occupies only 1 per cent less than A, and C occupies 39 per it less than that of B, but the ranking difference will be one step s in each case which is against the principle of statistics. The difence between the various ranks is not maintained which is not unim. Since the ranking coefficient method is based on the arithmetic ean, it suffers from the weakness of arithmetic average in which the

ality weightage is ignored.

Moreover, the method has an inherent weakness which makes it newhat insensitive as a measure of agricultural productivity. The akness arises from the neglect of areal strength of the crop for ich acre yields are taken into account for the calculation index of king coefficient. The weakness of this method becomes obvious en we consider the contribution of individual crops in the produc- ity of component areal unit. For example, in Uttar Pradesh, the tern districts of Gonda, Faizabad, Sultanpur, Deoria, Ballia, etc., w very high productivity of *bajra*, though only a fraction of 1 per it is devoted to this crop. Probably, the farmers of these districts, ough their power of selection, devote only the well drained ele- ed fields to this crop and consequently get high agricultural re- ns which alone should not be taken as the determinant of agricul- al productivity. Similarly, in Maharashtra, the districts of Ahmad- gar, Sholapur and Pune show very high agricultural productivity of garcane, though it occupies less than 1 per cent of the cropped land hese districts. Obviously, a crop which occupies a negligible por- n of the cropped land would contribute nothing to the agricultural iciency of the areal unit, though it may have a very high yield per e.

The weakness of the ranking coefficient method becomes more ar when we see Figure 7.9. The district of Shahjahanpur, which is of the agriculturally well developed districts of India and having ensive cultivation of wheat, sugarcane and rice, falls into the me- m productivity category, while many of the districts of eastern Ut- Pradesh and Bihar show high agricultural productivity which is in conformity with the prevailing socioeconomic conditions of se districts. Looking at the prevailing standards of living of the stern Uttar Pradesh and western Bihar it can be said that the for- r has a much better standard of nutrition and living, therefore the ductivity regions, delineated by the ranking coefficient method, not conform to the ground reality.

In the ranking coefficient method weight is not given to the value crops in terms of money. In fact, it is not the average yield per hec- e or the area occupied by a crop in an areal unit but the average put in terms of money per hectare at a given point of time that in-

fluences the farmer's capacity to apply inputs, the level of agricultural technology and the living standard and all these factors in turn determine the agricultural productivity of a unit within a given environmental set-up. This point can be illustrated with the help of the following example.

Suppose, in district X, barley, *bajra* and small millets have the ranks of 50, 21 and 10 respectively, resulting into the ranking coefficient of 27, while in the Y district the dominant crops are wheat, sugarcane and oilseeds which rank 60, 40 and 10 respectively. In case of Y the ranking coefficient would be 37. Thus, the ranking coefficient in district X growing inferior coarse varieties of cheap cereals would be higher to that of Y district in which costly crops of superior quality are grown. According to this technique, district X will get a higher rank in agricultural productivity as compared to Y though the farmers of Y district are getting more agricultural returns in terms of money. It is thus irrational and illogical to ignore the quality and price of the crop produced in a region.

Measurement of Agricultural Productivity in Terms of Money

Looking at the weakness of the ranking coefficient method advocated by Kendall for the measurement of agricultural productivity, a new technique has been developed in which all the crops grown in an areal unit are taken into consideration. The agricultural productivity should be measured in terms of total production converted into money, minus the inputs (farm family labour, cost of seeds, manure, chemical fertilizers, plant protection chemicals, hired draught force, implements and casual hired labour). The maintenance and repair of implements, depreciation of machinery and transportation cost have also to be substracted from the total production. Conversion of production into money equivalents removes the biasness towards the crops which occupy small proportion of the gross cropped area. In other words, production in terms of money gives adequate weight to the quality and total production of all the crops. Exclusion of any crop simply owing to its low hectareage is avoided. There are several crops like cotton, oilseeds, saffron, onion, spices, chillies, ginger, turmeric and tobacco, etc., which generally occupy small area but their returns in terms of money are always substantial. The exclusion of such crops may significantly change the level of productivity of a

component areal unit. This technique, though constrained by the non-availability of reliable data on price of commodities in the different parts of the area under study, provides a relatively better picture of agricultural productivity. This technique, however, involves arduous calculation and demands the use of computer for calculations.

The net output in terms of money may be obtained with the help of following formula :

$$PI = \Sigma(Y_{ij} \times C_{ij}) - P_{oc}$$

where PI means productivity index, Y_{ij} total production, C_{ij} market price and P_{oc} is the paid out cost (input cost).

This technique was applied on the production of all crops of the Sutlej-Ganga plain (India) for the determination of per acre return in terms of rupees for all the component areal units (districts).

Table 7.10

Sutlej-Ganga Plain : Yield per acre in Terms of Money (1991-94)

Level of Productivity	*Index Value (Rs. per acre/per annum)*
Very High Productivity	> 15000
High Productivity	> 12000
Medium Productivity	> 9000
Low Productivity	> 5000
Very Low Productivity	< 5000

The patterns of regional productivity of the Sutlej-Ganga plain have been plotted in Figure 7.10 which shows that all the districts of Punjab and Haryana, excepting Hissar, Sirsa and Mohindergarh, have very high agricultural productivity. The districts of Meerut and Rohilkhand divisions are also agriculturally well developed and their agricultural productivity is also very high. All the districts of very high productivity make a contiguous zone in the northwestern part of the Sutlej-Ganga plain. It is an extensively irrigated part of the country in which almost each acre of land has been brought under either canal or tubewell irrigation. The per acre yield in the very high productivity region is over Rs.15000 per acre per annum (Table 7.10). Wheat, rice, sugarcane/paddy and vegetables are the major crops of this region.

The agricultural productivity declines going south and eastward

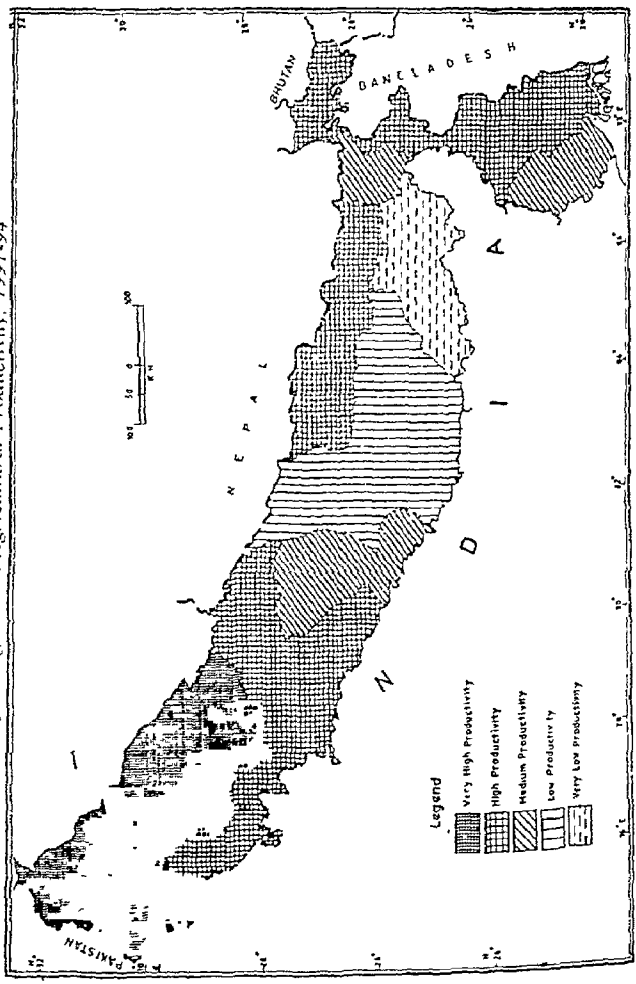


Figure 7.10

Sutlej–Ganga Plain, Agricultural Productivity, 1991–94

from the very high agricultural productivity region (Fig.7.10). The districts of Hissar, Sirsa, Mohindergarh, Gurgaon (Haryana), Pilibhit, Lakhimpur, Budaun, Shahjahanpur, Aligarh, Etah, Etawah, Mainpuri, Fatehpur, Kanpur, Allahabad, Gorakhpur, Deoria and Kushinagar (Uttar Pradesh), the northern districts of Bihar and most of the districts of West Bengal have high agricultural productivity The main crops of these districts are wheat, rice, sugarcane, jute, maize oilseeds and vegetables There crops are however, grown in different associations. The farmers of these districts are getting between Rs 12000 and Rs 15000 per acre per annum.

The central and southeastern Uttar Pradesh, Shahabad, Aarah, Kishanganj and Purnea districts of Bihar, and Midnapur and Bankura districts of West Bengal have medium productivity The average return per acre of land ranges between Rs. 9000 and Rs 12000 per annum. The low standard of living and poverty of the cultivators are the major barriers in the diffusion of new innovations and rice could not be diffused in these districts. The new seeds of HYV of wheat and rice could not be diffused in these districts

Most of the districts of Bihar lying to the south of the Ganga river have very poor agricultural productivity The farmers of this region are heavily dependent on the timely arrival of summer monsoon The small holdings, poverty and conservativeness of the farmers are the main hurdles in agricultural development The average yield per acre per annum in the very low productivity area is below Rs. 5000 There is an urgent need to accelerate farm production in the areas of low and very low productivity. The task is not easy as the poverty, orthodoxy and low risk taking capacity of the farmers are the main impediments. The increase in the level of productivity may, however, go a long way in removing the regional inequalities. The delineation of agricultural productivity regions by a sound statistical technique is a prerequisite for future planning and development of agriculture. Such an attempt would help in knowing the real causes of agricultural backwardness and will provide a sound base for the rural economic progress, making agriculture more viable and sustainable

Land Classification and Land Use Survey

The classification of land according to its quality for a particular pur-

pose is known as land classification. The concept of land classification is often used for agriculture as a whole, but assessment are sometimes made for single enterprise. The results are usually represented cartographically and may form a basis for planning decisions on applications for the conversion of agricultural land use to other uses.

In general, land use classification has two components, as under:

1. The assessment of physical quality and agricultural potential of land. This is also known as 'land capability'. The physical properties of land are almost unchangeable. In fact, the character and quality of land and its soil depend on the parent material, temperature, rainfall, water retaining capacity, soil texture, soil structure and humus contents. These properties of land do not change over shorter period of time.
2. The assessment of land quality under the prevailing set of socioeconomic circumstances including farm structure, availability of irrigation, relative cost of labour. capital inputs, level of technology and price stability. The economic and social controls on production are more variable.

A number of land use classification systems are in vogue in different countries of the world. The first systematic land classification was done by L.D. Stamp. In his land classification of Britain, Stamp adopted a seven-fold system, i e., (i) arable, (ii) heath and rough, (iii) pastures, (iv) orchards and nurseries, (v) meadowland, (vi) forest and woodland, and (vii) urban areas. The details and justification of this classification have been explained in Stamp's monumental work *The Land of Britain : Its Use and Misuse*. This classification helped in overcoming many of the problems pertaining to the demand of land after the Second World War. Subsequently, Coleman, a student of Stamp, adopted a classification of 13 major classes with various subdivisions, making 70 land use types in all. The International Geographical Union (IGU) resolved to produce a unified classification system for the whole world but in the absence of adequate and reliable data, particularly about the developing countries, it could not become possible.

In the United States of America, Sauer (1924) pioneered the land use survey. Subsequently, Jones, Finch (1925) stressed on the importance of land use classification for planning and development. In 1925, Whittlesey took into consideration several socioeconomic indicators (see Chapter 5) for the delineation of agricultural typologies of the world. Looking at the arduous and cumbersome nature of the task of land use survey and land use classification, the American geographers gave emphasis on sampling techniques. The sampling techniques were considered superior to field survey as they economize on time, effort and money.

In India, M. Shafi is the pioneer of land use studies. He published the *Land Use Survey in Easter Uttar Pradesh* in 1962. Under his supervision over two dozen students completed their doctoral theses in the field of agricultural land use studies.

The availability of satellite imageries has revolutionized the whole technique of land use classification. The main weakness of the traditional land use survey is that it gives only a static description of existing land use and is very time, effort and money consuming.

Land Suitability Survey

Land classification, on the basis of land capability, has been considered as a more important document for the planning and development of agriculture. Land capability classification is a scientific appraisal of the physical characteristics of land, its inherent soil qualities, and the farm management practices. The land capability maps are more useful for the delineation of problematic and potential arable lands.

In several developed countries land has been classified on the basis of land capability, suitability, agricultural productivity and land irrigability. Stamp, in 1960, introduced the concept of potential production unit(PPU) as a standard unit for land classification. A PPU may be defined as the potential production of one acre of good average farm land under good farm management practices. A rough scale of PPU was developed as under:

One acre of class I = 2.00 PPU
One acre of class II = 1.00 PPU
One acre of class III = 0.50 PPU

By applying the PPU technique for land classification one may assess the loss of cultivated land if that is devoted to some other uses(industries, housing, etc.). For example, if 100 acres of class II(medium quality) of land are used for the construction of a factory, it will be a loss of 100 PPU, while if the class I(good quality) land is used for establishment of that factory the loss will be equivalent to 200 PPU, and by constructing the factory in the class III category(poor quality), the loss will be to the extent of only 50 PPU. It will, therefore, be more judicious and rational to construct the factory on the poor quality of land where the loss of potential production units is the minimum. Thus, the potential production units is a good technique for the delineation of land capability regions.

Land Capability

Land capability is one aspect of land classification. For the determination of land capability, the usefulness of land for agriculture, forest and tourism is assessed solely on the basis of physical environmental factors. In other words, in land capability classification, the texture, structure of soil, aspect of slope, terrain, temperature, rainfall, runoff and water availability are taken into consideration. In this classification, there is, however, heavy reliance on soil survey results. Moreover, the present farm productivity or actual land use are ignored.

As a matter of fact, the loamy soil differs from the *regur*(black earth) soil and the lateritic soil is different from the red soil. These soils are suitable for the cultivation of different crops. For example, loamy soil is ideally suited for the cultivation of rice, wheat, sugarcane, jute, pulses, gram and oilseeds, while cotton performs well in the black earth soil. The cultivation of saffron is possible only in the *karewa* lands, while *bajra*(bulrush millet) grow well in the sandy soil. Thus, the land capability of a soil has certain physical properties which help in getting better agricultural returns of certain crops.

The assessment system devised by the Commonwealth Scientific and Industrial Research Organization(CSIRO) for use in Australia has been widely used elsewhere.

Land capability is usually presented cartographically either by type of terrain or by some judgement of potential agricultural productivity. Limited attempts have been made to produce land capabil-

ity assessment for recreational land use.

In India, the primary aim of soil survey was to achieve land capability classification. The All India Soil and Land Use Survey Organization, in 1960, has attempted such a classification Subsequently, inadequacies in the Soil Survey Manual were removed and the revised Manual was published in 1970. The All India Soil and Land Use Survey Organization(1970) has identified eight different land use capability classes as given below:

Land Suitable for Cultivation

Class I: Very good cultivable land with no specific difficulty in farming.

Class II: Good cultivable land which needs protection from erosion or floods, drainage improvement and conservation of irrigation water.

Class III: Moderately good cultivable land where special attention has to be paid to erosional control, conservation of irrigation water, intensive drainage and protection from floods.

Class IV: Fairly good land suited for occasional or limited cultivation, needs intensive erosional control, intensive drainage and very intensive treatment to overcome soil limitations

Land not Suitable for Cultivation

Class V: Very well suited for grazing but not for arable farming, needs protection from gullying.

Class VI: Well suited for grazing or forestry but not for arable farming.

Class VII: Fairly well suited for grazing or forestry but not for arable farming

Class VIII: Suited only for wildlife, recreational facilities and protection of water supplies.

Agroclimatic Regions of India

India is a country of great geographical diversity. The variations in its terrain, temperature, rainfall and soils have closely influenced the cropping patterns and other agricultural activities. For the planning

and development of agriculture, the Planning Commission and the National Remote Sensing Agency (NRSA) have divided the country into 15 agroclimatic regions. In the delineation of these agroclimatic regions, the physical attributes of the region and socioeconomic characteristics have been taken into consideration. The agroclimatic regions plotted in Figure 7.11 are :

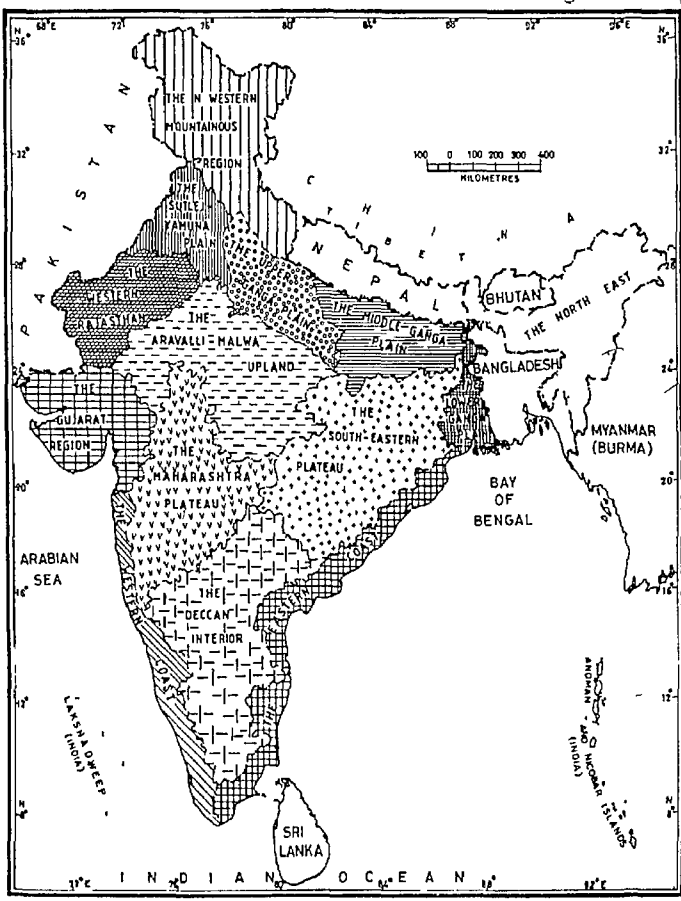
The northwestern mountainous region
The northeastern region
The Sutlej-Yamuna plain
The Upper Ganga plain
The Middle Ganga plain
The Lower Ganga plain
The southeastern plateau
The Aravalli-Malwa upland
The plateau of Maharashtra
The Deccan interior
The Eastern coast
The Western coast
The Gujarat region
The western Rajasthan
The Islands of Andaman & Nicobar

The Northwestern Mountainous Region

The northwestern mountainous agroclimatic region stretches over the states of Jammu & Kashmir and Himachal Pradesh and the Kumaun and Garhwal divisions (Uttrakhand) of Uttar Pradesh It has snow-covered peaks, dissected topography, steep slopes, perennial rivers, evergreen and deciduous forests, and thin cover of soils on undulating slopes. There are micro level variations in temperatures and rainfall. Summers are mild while winters are generally severe over greater parts of the region. The low temperatures, snowing and inclement weather in winters hinder the intensification of agriculture.

Agricultural activities in this region are largely confined to the valleys (Kashmir, Dun, Chamba, etc.), river terraces and gentle slopes of the 'Kandi' tracts. Rice in the valley floors, and maize in

Figure 7.11
India Agro-Climatic Zones



the hilly areas dominate the *kharif* land use Barley, wheat, oats, peas sown in October in some areas show a stunted growth during the winters when temperatures are generally below the freezing point. These crops harvest in the months of May and June while in the Suru

and Nubra valleys (tributaries of Indus) of Ladakh wheat is harvested in the month of July or August

This agroclimatic region is well known for the cultivation of orchards The apple orchards of Sopore, Srinagar and Baramulla (Kashmir), Kulu-Manali, Shimla and Kangra (Himachal Pradesh), and Ranikhat and Almora (Uttar Pradesh) are famous all over the country Apart from apples, apricot, almond, walnut, litchis, laokawt, cherry, peach, pears and superior quality of saffron are grown in this region The high altitude alpine pastures situated above 2000 metres, locally known as 'Dhoks' or 'Margs', are utilized by the Gujjars, Bakarwals and Gaddis for the rearing of their sheep, goats, cattle and horses The economy is largely agrarian and over 80 per cent of the total workforce of the region is directly or indirectly dependent on agriculture

Poor accessibility, soil erosion, landslides, inclement weather, inadequacy of marketing and storage facilities are the major problems of the region The agricultural potential of the region has not been utilized judiciously The standard of living of the rural communities is poor and they could not adopt the new agricultural technology like HYV of wheat and rice in a big way There is a great need of research and extension service for the agricultural development and planning of the northwest mountainous region of the country

The Northeastern Region

The northeastern region sprawls over the seven states, also known as the seven sisters of northeast India, i e , Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura It has two subdivisions (i) the valley of Brahmaputra, and (ii) the hilly tracts of the seven states Abundance of rainfall, especially during the summer season (April to October) high relative humidity and mild to warm temperatures are the distinctive characteristics of this region The warm and humid climate is quite conducive for the cultivation of crops throughout the year There are, however, micro level variations in the temperatures and rainfall recorded in the region The textural properties of soils also vary from altitude to altitude and from the Brahmaputra valley floor to the high peaks of hilly tracts

Rice is the dominant crop in the region The undulating terrain

on both sides of the Brahmaputra and its tributaries covered with highly productive alluvial soils are ideally suited for the cultivation of tea. Jute, pineapple, ginger, oranges, guava, maize, potatoes and vegetables are the other crops grown in the region.

In the hilly areas *jhuming* (shifting cultivation) is the main agricultural system. The main characteristics of shifting cultivation are : (i) rotation of fields rather than crops, (ii) absence of draught animals and manuring, (iii) use of human labour only, (iv) short period occupancy alternating with long fallow periods, and (v) use of primitive simple tools like hoe, dibble sticks, *dao* and knives (for details, see Chapter 5). Shifting cultivation is, however, damaging the ecology and environment and special measures need to be taken to convert *jhuming* into sedentary agriculture.

The Sutlej-Yamuna Plain

The greater parts of the states of Punjab and Haryana fall in the Sutlej-Ganga plain. It has a general gradient from northeast to southwest. This region is characterized with great continentality. The annual range of temperature is high. The mean maximum in May often crosses 45^0 C while the mean minimum temperature in the month of January often reads below freezing point. The average annual rainfall ranges between 50 cm (Firozpur) and 85 cm (Ambala). In winter (December-Februrary), there is comparatively more rainfall from the western disturbances.

The Sutlej-Ganga plain is extensively irrigated by canals taken out of the Sutlej, Beas and Yamuna rivers. The farmers have installed tubewells and pumping sets in their holdings to ensure irrigation to the crops all the year round. Rice, sugarcane, maize, cotton, fodder and pulses are the major *kharif* (summer) crops while wheat, peas, barley, gram, and oilseeds are grown in the *rabi* (winter) season. The Green Revolution has achieved great success in this region. This is one of the agriculturally most developed regions. The farmers are generally adventurous who are good receptive to new innovations in agriculture. Agriculture is generally market oriented and now farmers are paying more attention towards orchards (mango, guava, kinnu, etc.) and vegetable cultivation. Dairying is also an important economic activity in the region.

alinization, soil erosion and waterlogging are the major prob- of the Sutlej-Yamuna plain. There is an urgent need for the ,e in the present rice and wheat rotation of crops as both these are soil exhaustive.

Upper Ganga Plain

pper Ganga plain stretches over the greater parts of the Ganga- ma Doab, and Rohilkhand and Lucknow divisions. It is drained e Ganga river and its tributaries. The general slope is from west to southeast. It is covered by the highly productive alluvial deposited by the perennial rivers descending from the Himala- t has subhumid climate with warm summers and cold winters. rence of *Aandhi* (dust-strom) in the months of May and June is ılar feature. The average annual rainfall varies between 65 cm 20 cm. The region is adequately irrigated by canals, tubewells umping sets. Over 80 per cent of the recorded rainfall comes the summer monsoon, originating from the Arabian Sea and the of Bengal, while the remaining rainfall in the winter season s from the western disturbances.

he region has the dominance of rice, sugarcane, maize, pulses illets (fodder) in the *kharif* season and that of wheat, oilseeds, s (gram, lentil), potato and vegetables in the *rabi* season. It ha rous orchards of mango, guava, peaches, litchis and the hec- ge under orchards is significantly increasing.

luctuations in the price of sugarcane and inadequacy of market- ıd storage facilities are the main problems. Excessive irrigation garcane, paddy and wheat crops are resulting into the formation line and alkaline soils. The underground water table is also ily dwindling and getting lowered. The Green Revolution has its mark in this area and the farmers are increasingly interested cultivation of rice, sugarcane and wheat. All these crops are xhaustive and therefore emphasis should be laid on the cultiva- of leguminous crops.

Middle Ganga Plain

Middle Ganga plain stretches over the eastern Uttar Pradesh and reater parts of Bihar, north of the Chotanagpur plateau. It forms sitional region between the Upper and the Lower Ganga plains.

It has hot and humid summer and mild winter season. The mean maximum and mean minimum temperatures in the summer and winter seasons read over 40^0 C and 5^0 C respectively. The average annual rainfall varies between 100 cm and 150 cm. Most of the rainfall comes from the summer monsoon originating from the Bay of Bengal.

Covered with fertile alluvial soils, the region is ideally suitable for the cultivation of rice, maize, pulses, sugarcane and a wide variety of vegetables. Wheat, gram, oilseeds (mustard, rapeseed, sunflower), and vegetables are the dominant *rabi* crops. A wide variety of subtropical fruits (mango, litchis, guava, banana) are also grown in the middle Ganga plain.

Soil erosion, alkaline and saline formations and waterlogging are the main problems of the region. Small size of holdings and poverty of the farmers are coming in the way of adoption of HYV. The Green Revolution has not made much impression on the land use of this region. The farmers are tradition bound and their risk taking capacity is low. Poor means of communication and transportation, inadequacy of marketing and storage facilities, illiteracy, orthodoxy and poor standard of food and nutrition are some of the problems which are the main impediments in agricultural development of the Middle Ganga plain.

The Lower Ganga Plain

It covers the lower portion of West Bengal. Characterized by numerous ox-bow lakes and backwaters, it is a region covered with fine-clayey to silty-clay soils. It has a hot and humid climate. The mean minimum temperature never goes below 15^0 C. The alluvial soil and hot and moist climate are conducive for the cultivation of rice and jute. Two to three paddy crops in a year is the usual practice. Some of the farmers have gone for wheat cultivation in the winter season. Moreover, a wide variety of tropical fruits, i.e., mango, guava, coconut, arecanut, jack fruit, etc., are grown. The farmers generally practise pisciculture in their ponds. There is enormous scope for pisciculture and aquaculture in the region.

Small size of holding and poverty of the farmers are the main barriers in the agricultural development of the region. The growing

heavy pressure of population on agricultural land is a cause of concern and rural unemployment which deserves immediate attention.

The Southeastern Plateau

The southeastern plateau covers the whole of Chotanagpur plateau, Baghelkhand and Mahanadi basin. In other words, this region extends from Baster (Madhya Pradesh) in the southwest to Dumka and Sahibganj (Bihar) in the northeast (Fig. 7.11). It consists of the old Archaen structures to Gondwana, Tertiary, Quarternary and recent alluvial formations. Climatically, it is hot and humid receiving over 125 cm of average annual rainfall. Over 85 per cent of the total rainfall is recorded between June and October. The soils, excepting the Mahanadi basin are, however, generally poor. There are isolated tracts of leteritic soils, while most of the region is covered by the poor leached red soil. Irrigation by canals and other sources is possible only in about 20 per cent of the cultivated area. In fact, the scarce underground water table and rugged topography are the great barriers in the development of irrigation facilities.

Rice is the dominant *kharif* crop, grown largely in the fertile valleys and basins called 'Dons' in Chotanagpur plateau, while the uplands are devoted to *arhar* (pegion pea). In the *rabi* season some suitable fields are devoted to gram and lentil while the unirrigated tracts are left as fallow lands.

Soil erosion and inadequate irrigation are coming in the way of intensification of agriculture in this region. Agriculturally, it is one of the backward regions where the farmers are tradition bound and rural unemployment is a chronic problem.

The Aravalli-Malwa Plateau

The Aravalli-Malwa upland stretches over western Madhya Pradesh and the eastern parts of Rajasthan, east of the Aravalli mountains. It has one of the oldest rocks in the world. The average annual rainfall ranges between 50 cm and 100 cm occurring mainly during the rainy season. It receives rainfall from the summer monsoons, originating from both the Arabian Sea and the Bay of Bengal. The southwestern part of the region has *regur* (black earth) soil

Cotton, soyabean, millets, maize and pulses are the dominating crops in the *kharif* season, while wheat, oilseeds, gram and lentil are

grown in the *rabi* season

Since irrigation facilities are not developed, the agriculture is largely dependent on monsoon Looking at the uncertainty and high variability to rainfall, dry farming practices are imperative to get good agricultural returns and to make agriculture sustainable The Chambal Canal, traversing the districts of Kota, Sawai Madhopur, Morena, Gwalior and Bhind has helped in the adoption of HYV of wheat and rice in its command area The underground water table is scanty and its utilization is constrained by the hard rock formations

Agriculture in this region is largely dependent on the timely arrival and distribution of rainfall The farmers diversify their cropping patterns to get some returns even under the adverse rainfall conditions Agriculturally, this is a less developed area and the government has to adopt a package programme to make agriculture a remunerative economic activity

The Plateau of Maharashtra

The plateau of Maharashtra stretches over western Madhya Pradesh, the whole of Maharashtra to the east of the Western Ghats Covered with thick black earth soil it has high temperatures throughout the year The mean monthly temperature is above 20^0 C even in the month of January Being in the rain shadow area of the Western Ghats it receives little rainfall, ranging between 50 cm and 75 cm annually It is a drought prone area in which the variability of rainfall is very high The irrigation possibilities are quite limited This region is conducive for the cultivation of cotton, pulses, oilseeds, wheat, gram, soyabean, maize, millets, pulses and sugarcane Cultivation of sugarcane is, however, confined to the areas where irrigation facilities are available Banana, grapes, oranges and chikoo flourish in the irrigated areas Millet is the staple food Agriculturally, it is an underdeveloped area and has enormous potential for the cultivation of cotton and citrus fruits Scarcity of irrigation water is the major problem of the region

The Deccan Interior

The deccan interior sprawls over the greater parts of Karnataka, Andhra Pradesh and Tamil Nadu uplands from the Adilabad district in the north to Madurai district in the south (Fig 7 11) It is generally a

water deficient and drought prone region which is characterized with granite gneiss basement on which poor red soils have developed in favourable localities.

Millets, ragi, rice, cotton, groundnut and pulses are the dominant crops in the region. The inadequacy of irrigation facilities have made the agriculture of this region highly vulnerable and least sustainable.

The Eastern Coast

The eastern coast stretches over the entire tract of the Eastern Ghats It sprawls from the district of Balasore in the northeast to Kanyakumari in the south. Covered with the alluvial soils deposited by the Mahanadi, Godavari, Krishna and Kaveri, it is a humid region which records average annual rainfall over 100 cm. It receives rainfall from the summer as well as winter monsoons. The temperatures remain high throughout the year.

Rice is the leading crop. In favourable locations, the farmers grow two paddy crops in a year. In the coastal area of Orissa, jute is an important cash crop. Tobacco is an important cash crop in the coastal Andhra Pradesh. Banana, coconut, cashewnut, arecanut and citrus fruits are abundantly grown in the region. Agriculture in this region is well developed and HYV of rice have been largely adopted in the region. The Kaveri delta (Thanjavur district) is one of the areas in which the Green Revolution is a big success. The region also has enormous potential for aquaculture.

The Western Coast

The western coast sprawls over the western fringes of the states of Maharashtra, Karnataka and Kerala (Fig. 7.11). This is a humid region which records abundant rainfall from May to October from the monsoon originating from the Arabian Sea It is characterized by fertile valleys and undulating slopes.

Rice is the leading crop in the region. Coconut, coffee and tea are the important cash crops. In addition to these, a variety of spices and cashewnuts are grown on the lower slopes of the Western Ghats. Coffee and tea are largely grown in the Shimoga, Chikmaglur and Hassan districts of Karnataka. The region has enormous potential for the development of spices, coffee, coconut and tropical fruits cultivation

The Gujarat Region

The state of Gujarat has a distinct geographical region and possesses a unique agroclimatic personality. The coastal areas are wet, recording over 100 cm rainfall while the interior parts (districts Mahesana, Kheda, etc.) are dry. Parts of this region are covered by black earth soil, while greater part of the state has light alluvial soil. These agroclimatic conditions are most suitable for the cultivation of groundnut, cotton and wheat. The cultivation of wheat is a recent phenomenon in the region. The HYV of wheat have been diffused in the Gujarat region during the later parts of the 1960s and early parts of the 1970s. The Rann of Kutch has low agricultural productivity. Wherever irrigation has been developed, the farmers are harvesting good crops of wheat during the *rabi* season.

The Western Rajasthan

The western Rajasthan consists of the Thar desert of the Marwar and the Aravalli ranges of Mewar. From the western flank of the Aravallis to the Indo-Pakistan boundary is the Thar desert which has great variations in geomorphological features The Aravallis are highly worn out residual ranges developed on folded structures with quartzites, conglomerates and grits. The undulating slopes of Aravallis have an apron of soil at the base. The desert is covered by sandy soil. The Thar desert is characterized with sanddunes. The Jodhpur basin is the largest and is breached by the Luni river There are micro level variations in the topographical features The sand-dunes of migrating character have a general southwest-northeast trend They are more stabilized in the east and northeast. The other contrast is that of stony deserts and wastes occurring extensively as the final remnants of residual hills and tors; they are more extensive in the Jaisalmer-Barmer region.

These variations in local topography materially influence soils, vegetal cover and land use. The inhabitants of the Thar desert draw their major subsistence support from the pastoral activity. Almost every agricultural community practices grazing as a part of its economy. The Raikas of Thar desert are professional graziers who seasonally reach with their flocks up to the Yamuna banks. The socio-economic status of the people is judged by the number of cattle,

camel, goat and sheep as they provide energy, milk and milk products, manure, skins, bones and wool.

The Indira Gandhi Canal has transformed the rural economy, particularly that of Ganganagar and Bikaner districts. With the help of irrigation, the farmers have brought more area under cultivation. In the irrigated tracts a better soil management demand a better understanding and improved technology, if the problems of salinization and waterlogging are to be checked. The ecosystems of this region are highly fragile. The man-environment relationship in the region is very delicate and therefore an indepth study of the micro ecosystems is required.

The Islands of Andaman & Nicobar

The Andaman and Nicobar is a string of over 300 richly forested tropical islands which lie in the middle of the Bay of Bengal, two-thirds of the way between India and Myanmar (Burma) and stretches almost to the tip of Sumatra. There is little seasonal variation in climate. Continuous sea breezes keep temperatures within the 23° C to 31° C range and the relative humidity at around 80 per cent throughout the year. The southwest monsoons come to islands between mid-May and October and the northeast monsoons between November and January. Thus, these islands receive abundant rainfall and have hardly any winter season.

These islands are conducive for the cultivation of tropical crops Spices, coconut, rice, maize. oilseeds and pulses are the main crops. Being covered by dense forests the agriculture is largely confined to the littorals of main islands. There is, however, enormous potential for silviculture and aquaculture.

Poor accessibility and humid climate are the main barriers in the agricultural development of this region. The hot and humid climate provides a good breeding ground for mosquitoes. Malaria is a common disease which affects the efficiency of the cultivators adversely.

The agroclimatic regions have been delineated with a set objective to prepare suitable agricultural strategy for each one of them. The experience of the cultivators and agricultural scientists show that each agroclimatic region needs the adoption of better seeds and technology. Such a strategy will not only increase the agricultural pro-

ductivity but will also make the ecosystems of each agroclimatic region more cleaner and sustainable

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8 Models in Agricultural Geography

Since the Second World War geographers have increasingly concentrating on the themes and approaches of paradigm, model building, theories and law making for geographic generalization. This is also known as 'model building'.

The term 'model' has been defined differently by different geographers and social scientists. In the opinion of Skilling (1964), a model is "either a theory, a law, a hypothesis, or a structured idea". Most important from the geographical point of view, it can also include reasoning about the real world (physical and cultural landscape) by means of relation in space or time. It can be a role, a relation or an equation.

According to Ackoff, a model may be regarded as the formal presentation of theory or law by using the tools of logic, set theory, and mathematics. According to Haines-Young and Petch, "any device or mechanism which generates a prediction is a model". Accordingly, like experimentation and observation, modelling is simply an activity which enables theories to be tested and examined critically.

At present most of the geographers have conceived models as an idealized or simplified representation of reality (geographic landscape and man-nature relationship).

Significance of Agricultural Models

Agricultural geography deals with the spatial distribution of agricul-

tural activity. The agricultural landscape of any region is, however, complex and cannot be comprehended easily. Since the geoclimatic and socioeconomic conditions vary from place to place, there is great diversity in the agricultural activities. The basic aim of agricultural models is to simplify a complex agricultural mosaic to make it more amenable to investigation. Thus, agricultural models are tools which allow hypotheses and theories to be tested. In brief, there are predictive devices. Modelling in agricultural geography is done owing to the following reasons:

1. A model based approach is often the only possible means for arriving at any kind of quantification for formal measurement of unobserved or unobservable phenomena.
2. Models help in estimation, forecast, simulations, interpolation and generation of data. The future use of land, cropping patterns, crop combinations, degree of commercialization and sustainability of agriculture may be predicated with the help of agricultural models
3. A model helps in describing, analyzing and simplifying a geographical system. Location theories, zoning of agricultural land use can be easily understood and predicted with the help of models.
4. The enormousness of agricultural data is increasing with the passage of time which is becoming more difficult to comprehend. Modelling is taken for structuring, exploring, organizing and analyzing the data through discriminating pattern and correlation.
5. Agricultural models help in improving the understanding of causal mechanism, relationships between micro and macro properties of a system and the environment.
6. Models provide framework within which theoretical statements can be formally represented and their empirical validity then may be put under scrutiny.
7. Modelling provides linguistic economy. For example, the $d = \frac{\Sigma d^2}{n}$ is a concise mathematical model which if described will cover a paragraph. Thus, all the models, especially the

mathematical models, economize on language.

8. Models help in squeezing out the maximum information from the available data.
9. Models tempt us to formulate hypothesis and help in making generalization.
10. Models form stepping stones to the building of theories and laws. The theories and laws stimulate to probe more and to carry out more research.

Limitations of Models

Following are the limitations of models:

1. Agricultural models are the selective pictures of the earth surface. The man-environment relationship and the processes that result into agricultural activities and cropping patterns are highly complex. In other words, a model does not include all the physical and cultural attributes of a region. In fact, they are the selective pictures of the earth surface. The main objection against modelling is that the modeller may simplify the complexities of geographical realities too much or too little. This oversimplification generates misunderstanding and ultimately leads to wrong predictions.
2. The second objection to modelling is that the modellers may concentrate on wrong things. Sometimes the modeller may neglect to fulfil the basic criterion of simplification. They may apply the principal component analysis and stepwise regression. These techniques often produce models more complicated than the original data.
3. There are many geographers who feel that formulation and application of modelling in certain branches of geography is neither appropriate nor desirable. In their opinion model building in human geography, social geography, cultural and agricultural geography may distort the geographical reality by putting more emphasis on some facts and less emphasis on others.
4. Geography is not a pure physical science as it has a component of human beings. Man is a culture building animal who

is constrained by numerous values and norms in his behaviour. Models may not properly adjust and interpret the normative questions like beliefs, values, emotions, attitudes, desires, aspirations, hopes and fears. It is because of these limitations that models cannot be taken as dependable tools for explaining correctly the geographical reality.

5. Despite the economy of words and mathematical language, few geographers feel comfortable with mathematical symbolism and are thus largely apprehensive of the generality, clarity and elegance of the models.
6. Many of the models are difficult to understand even by the policy makers, clients and the public at large.
7. Most of the models are inadequate by themselves. Any model must be continually subjected to resassessment, modification and replacement. In fact, growth of knowledge is not a well regulated activity where every generation automatically builds upon the results achieved by the earlier workers.
8. Model building demands considerable reliable data. Such data is rarely attainable in the developing countries. Any set of data collected in the developing countries has many pitfalls and shortcomings. A model developed on the basis of weak and unreliable data is bound to give only a distorted picture of the geographical reality. It has also been observed that generalizations made with the help of models are bringing exaggerated results leading to wrong predictions.
9. The models developed in the developed countries when applied to the developing countries generally give wrong results. This is mainly because the sociocultural milieu of the two societies differ substantially from each other.

Classification of Agricultural Models

For a systematic understanding of agricultural activity the models of agricultural geography may be classified into:

1. Normative or economic models
2. Descriptive models

The normative or economic models discuss what ought to be the agricultural activity under certain assumptions, while the descriptive

models explain what is actually existing. The locational models like that of von Thunen, input-output and diffusion models are the examples of normative models. The experimental models (specimen farm models), mathematical models (combinational analysis), land capability, carrying capacity models are some of the examples of the descriptive models.

A concise account of the normative models has been presented in the following paras:

Input-Output Model

It is an analytical and mathematical approach to the description of an economy, which takes explicit account of connections between sectors. The input-output model provides a detailed description of interrelationships and linkages between the output and the various inputs.

The input-output model was invented by the distinginshed Russian economist R.H. Kantorovitch and developed by his pupil W.Leontief in USA. This model has been used by Peterson and Heady (1956) and Carter and Heady (1959) to analyze the interrelationships among the various regional and commodity sectors of agriculture and the effect of policy changes on the patterns of agricultural production. The main problem of the input-output model is the difficulty of obtaining reliable regional and inter-regional data needed for input-output analysis.

Decision Making Model

The decision making models have been a subject of great interest since 1960. These models were developed to deal with the problem of optimizing production in the light of incomplete information relating to risk or uncertainty in production, which suggests that actual decisions will be different from the decision of *economic man.*

The crux of of the decision making model is the recognition that real world location decisions are seldom if ever optimal in the sense of maximizing profits or minimizing *resources* used. The advocates of these models differentiate between the actual human beings and the economic man. In the real world decision makers consider only a limited number of alternatives, closing one that in broadly satisfactory rather than optimal. Contrary to this, the economic man is supposed to have all information about the risk, etc., who tries to obtain

the optimum benefits under a given geographical condition. The optimizing capacity of economic man has been considered as unrealistic in the real world. The assumption that economic man has the full knowledge of the environment in unrealistic.

The decision making perspective in location analysis has followed two routes—theoratical and empirical. The search for a theoretical framework for studies of location behaviour under conditions of *risk* and *uncertainty* has led geographers and regional scientists into such fields as game theory and organization theory. The light shed on actual decision making has, however, been very limited.

An empirical approach promises more in a field where the emphasis is so much on individual practice. There was a tradition of survey analysis in agricultural and industrial location studies well before the behavioural movements penetrated the subject. Such research often revealed the importance of 'purely personal' factors. The empirical approach holds out the prospect of generalizations that relate to the process of location decision making to the nature of organization concerned.

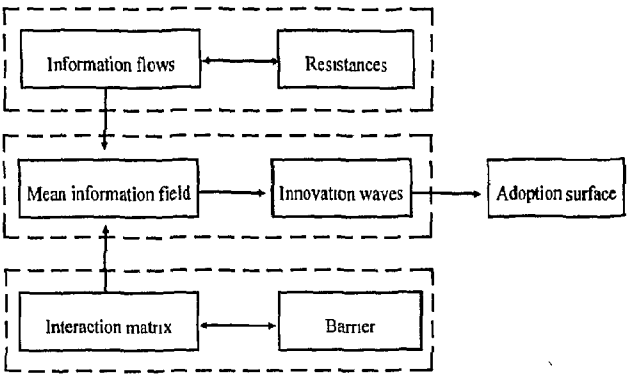
The main criticism against the decision making model is that while qualities of place (environment) as people evaluate them do influence decisions, there are many other considerations of a fortuitous and seemingly irrational nature. Moreover, the decision making models do not consider the multiple factors which determine land use patterns. These factors include the geoclimatic as well as socioeconomic conditions. Since better far is linked with attitude, motivation, information and communication which come through diffusion, there is need to examine briefly the diffusion model.

Diffusion Model

The spread of a phenomenon over space and through time is known as diffusion. The main objective of diffusion model is to account for the dispersal of cultural traits, agricultural practices, crops, and disease from a given region. It was Sauer (1941) who advocated the approach of diffusion model in cultural geography. In Sauer's view, diffusion—the filling of the space of the earth—was a general problem of social science. A new crop, craft or technique is introduced to a *culture area*. Sauer argued that one of the tasks of geographers is to

reconstruct diffusion pathways (routes) and to evaluate the influence of physical barriers. Subsequently, Hagerstrand made a systematic and formal study of innovation diffusion. The theoretical structure behind Hagerstrand's model is summarized below in Figure 8.1:

Figure 8.1
Hagerstrand's Diffusion Model



It will be seen from Figure 8.1 that the mean information circulates through a regional system. These flows are modulated by both physical barriers and individual resistences which together check the transformation of information into innovation and so shape successive diffusion waves which break onto the adoption surface. He generalized that the probability of diffusion declines as distance from the innovating centre increases. For most people interaction with other individuals is spatially restricted. The probability of contact declines as the distance between individuals increases, or the spatial development of many diffusion processes seems to be characterized by the addition of new adopters around the original nuclei of carriers of an innovation. The relationship or contiguous growth has been called the 'neighbourhood effect'.

In ascertaining the neighbourhood effect Hagerstrand made the following assumptions:

1. Only the carrier possessed the information (innovation) at the

beginning.

2. The probability of the innovation being accepted varied on account of variable levels of resistance to an innovation on the part of receivers.
3. The information is received orally at face to face (pairwise) meetings between the potential adopter and the carrier, i.e., through personal contact.
4. The probability of a potential adopter being paired with a carrier had a strong inverse relationship with the adopter (receiver) of the innovation.
5. The information is passed at certain specified times and intervals, particularly before the sowing period or at the time of sowing in different cropping seasons.
6. At each of these times every carrier (knower) passes on an innovation to another person (non-knower).

The diffusion model advocated by Hagerstrand may be applied in the adoption of an agricultural innovation. Information about an agricultural innovation may be diffused either by personal contact or technological means of communications. The adoption and imitation of new agricultural technology varies over space and time owing to the physical, socioeconomic and cultural barriers. However, personal contact plays a vital role in the adoption of an innovation. Apart from distance decay the innovations are diffused step by step. In fact, the educated, progressive big farmers adopt an innovation first while the small farmers with orthodox attitude adopt them slowly. The risk taking capacity differs from large to small farmers and that also hampers the adoption of innovations by the small and marginal farmers.

von Thunen's Model

This model was devised by von Thunen who was the forerunner among the theorists who have attempted to explain the organization of space through a workable model He developed a crop theory and crop intensity theory. In constructing his model, he used Mecklenburg, near Rostock in Germany, as the area of study. He operated this estate for forty years until his death. Most of the data used in explaining his theory were obtained by him through practical experience, in-

cluding detailed cost accounting of his estate. He attempted to construct a theoretical model of land use pattern, giving a particular arrangement of towns and villages in a situation experienced in Mecklenburg The main aim of von Thunen's analysis was to show how and why agricultural land use varies with the distance from a market. He had two basic models:

1. The intensity of production of a particular crop declines with the distance from the market. Intensity of production is a measure of the amount of inputs per unit area of land; for example, the greater the amount of money, labour and fertilizers, etc., that are used, the greater the intensity of agricultural production.
2. The type of land use will vary with the distance from the market.

The land use and crop intensity model of von Thunen is based on certain assumptions which have been described as under:

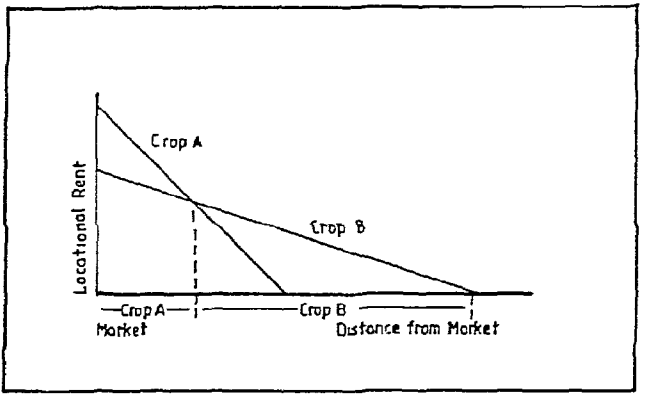
1. An 'isolate estate' (no links with the rest of the world) with one city at the centre of an agricultural area.
2. The city is the sole market for the surplus production from the agricultural area, and the agricultural area is the sole supplier to the city.
3. In the market of the city all the farmers receive the same price for a particular crop at any one time.
4. This agricultural area is a uniform plain over which soil fertility, climate, and other physical factors do not vary. There are no physical barriers to movement across the plain.
5. Farming was conducted rationally; this means that all farmers are economic men who aim to maximize their profits and have full knowledge of the needs of the market.
6. There is only one form of transport (in those days horse-carts and boats). The transport network in the region—both roads and navigable canal—was poor and the cost of transport increased at a constant rate.
7. The town existed in the centre of the agricultural land which

had no counter magnets in its vicinity.

von Thunen's model examines the location of several crops in relation to the market. The location of crops, according to him, is determined by (i) the market prices, (ii) transport costs and (iii) the yields per hectare. The transport cost varies with the bulk and the perishability of the product. The crop with the highest locational rent for the unit of land will always be grown, since it gives the greatest returns and all farmers attempt to maximize their profit. Two crops may have the same production costs and yields but difference in transport costs (per tonne/kilometre) and market prices influence the decision making of the farmers. If A commodity is more costly to transport per tonne/kilometre and it has a higher market price, A will be grown closer to the market than B (Fig.8.2).

Figure 8.2

Two Crops Types Locational Rent and Distance from Market

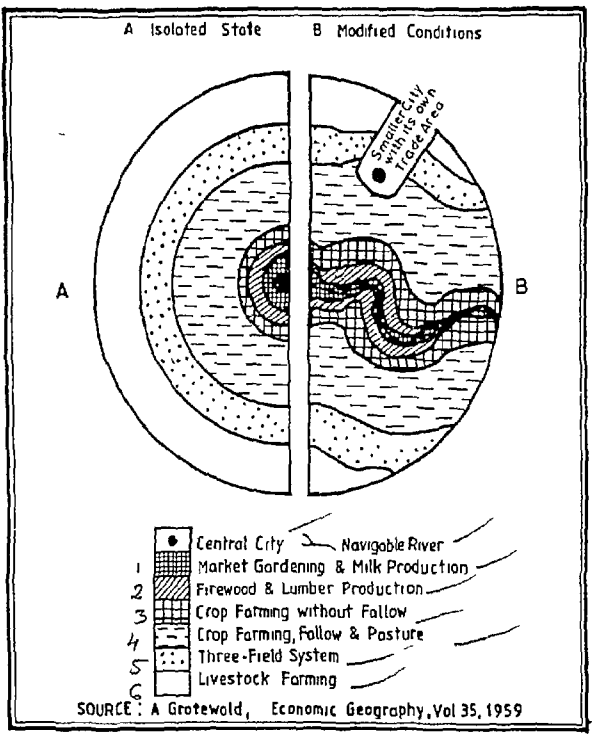


The locational rent of A decreases more rapidly than that of B, because of A's higher transport costs. As the market price of A is greater than B, the total revenue is higher at the market for A than B. Thus, the market of the locational rent of A is greater than B, because production costs are the same and no transport costs are incurred. If the market price of B was greater than that of A, A would not be grown at all.

On the basis of these assumption von Thunen constructed a land use model, having a number of concentric zones around each town. The perishable, bulky and/or heavy products, according to this model, would be produced in the belts nearer the town. The more distant belts would specialize in products which were less in weight and volume but fetched higher price in market as they would afford to bear relatively higher transportation costs. The final model was conceived having specialized agricultural enterprises and crop-livestock combination. Each belt, according to von Thunen, specializes in the production of those agricultural commodities to which it was best suited (Fig.8.3).

Figure 8.3 Concentric circles of Lan

von Thunen's Agricultural Zones



The land use model propounded by von Thunen suggests that the duction of fresh milk (in the context of Europe) and vegetables concentrated in the zone I nearest to the city, because of the per-ibility of such products. In this zone, the fertility of land was ntained by means of manuring and, if necessary, additional ma-e was brought from the city and transported to short distances to farm. The zone II was used for production of wood, a bulky prod-in great demand in the city as a fuel in the early part of the nine-th century. He showed, on the basis of his empirical data, that stry yielded a higher locational rent, since its bulkiness meant tively higher transport cost. Beyond the forest belt were three es where rye was an important market product. The difference be-en the zones was in intensity of cultivation. As the distance from market increased so the intensity of rye production decreased a consequent reduction in yields. There was no fallowing and uring to maintain soil fertility.

In the next zone IV the farming was less intensive. Farmers used ven-year crop rotation in which rye occupied only one-seventh of land. There was one year of rye, one of barley, one of oats, three astures and one of fallow. The products sent to the market, were butter, cheese, and occasionally, live animals to be slaughtered e city. These products did not perish so quickly as fresh milk and etables and could, therefore, be produced at a considerably ter distance from the market. In the most distant of the zones plying rye to the city zone V, farmers followed the three field sys-. This was a rotation system whereby one-third of the land was l for field crops, another one-third for pastures and the rest left w. The farthest zone of all, i.e., zone VI was one of the livestock ing. Because of the distance to market, rye did not produce so a rent as the production of butter, cheese or live animals (ranch-. The rye produced in this zone was solely for a farm's own con-ption. Only animal produce were marketed. •

The economic rent considering three crops (horticulture, forest lucts and intensive arable cereals) has been plotted in Figure 8.4, le Figure 8.5 shows a simplified model of concentric zones. It be seen from Figure 8.5 that zone I in which the economic rent gh is devoted to horticulture (fruits and vegetables), while zone

Figure 8.4

von Thunen Economic Rent Considering Three Crops

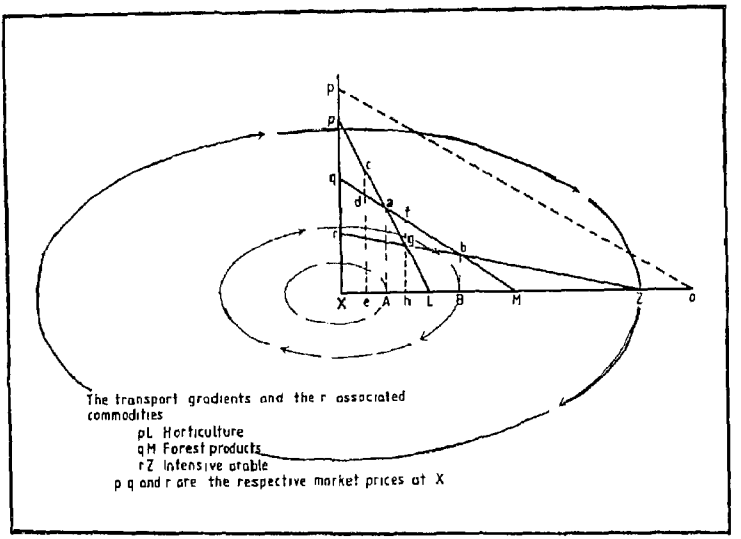
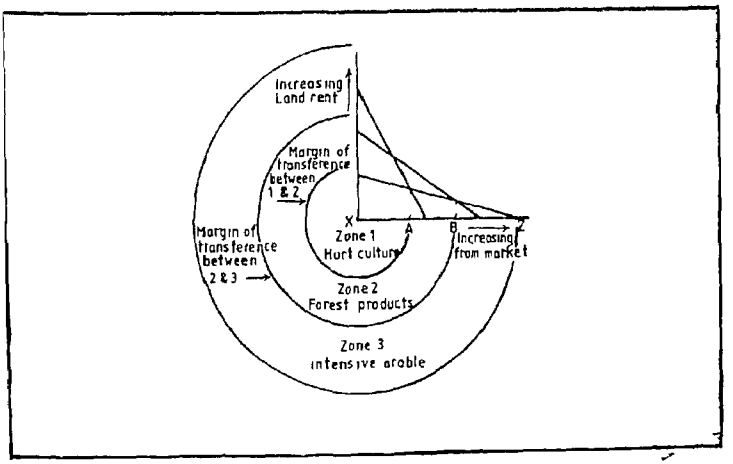


Figure 8.5

von Thunen A Simplified Model



II was devoted to forest products (fuelwood, etc.) as the transportation cost of fuelwood is high. The zone III is that of intensive arable land devoted to cereal crops.

Finally, von Thunen incorporated two examples of modifying factors in his classic model (Fig.8.3). The effect can clearly be seen of a navigable river where transport was more speedy and cost only one-tenth as much as on land, together with the effect of a smaller city acting as a competing market centre. Even the inclusion of only two modifications produces a much more complex land use pattern. When all the simplifying assumptions are relaxed, as in reality, a complex land use pattern would be expected.

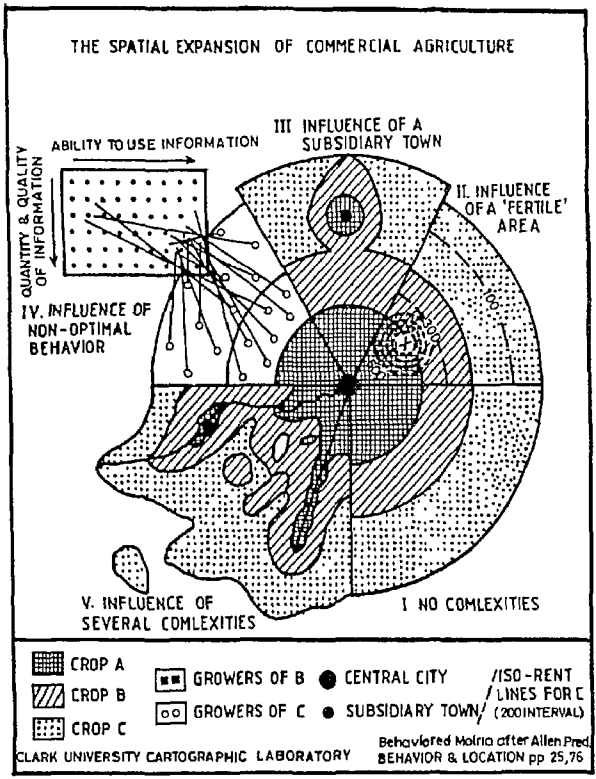
In fact, von Thunen applied marginal economic rent or land rent in relation to distance from the market. he applied marginal economics to the problem of cost substitution with increasing distance (von Thunen, 1826; Gotewald, 1959; Chisholm, 1962; Hall, 1926). The catalytic factor in von Thunen's model was transport cost and the main assumption was the assumption of an 'isolated estate'

A more complicated picture under commercial agriculture has been presented in Figure 8.6. In the modified von Thunen model, the influence of fertility, subsidiary town, information, etc., has been incorporated. The iso-rent lines at an interval of 200 have also been plotted. It will be seen from Figure 8.6 that the concentric zones of von Thunen model get modified under the impact of various, physical, socioeconomic and cultural factors. The influence of availability of information also substantially modifies the concentric zones of agricultural land use (Fig.8.6).

In many of the underdeveloped and developing countries of the world, in both the villages and towns, cropping belts are found. In the villages of the Great Plains of India similar patterns can be observed. The highly fertile and adequately manured lands around the village settlements are devoted to the perishable and more fertility requiring crops, e g., vegetables, potatoes, oats and orchards in the land lying in the middle belt; crops like rice, wheat, barley, pulses, sugracane, gram, maize, etc., are grown subject to the texture, drainage and other properties of the soils. In the outer fringes fodder crops and inferior cereals (*bajra*, millets) are sown. After the introduction of tubewell irrigation in the Great Plains of India, this pattern has, howev-

Figure 8.6

The von Thunen Zones. Under Several Complicating Conditions



er, been largely modified as the farmers with better inputs are able to produce perishable crops even in the distant fields from the settlements. The consolidation of holdings in India has also modified the crop intensity rings as each of the farmers is interested in growing the commodities for his family consumption as well as some marketable crops for earning cash to clear his arrears of land revenue and irrigation charges and to purchase the articles from the market for his family consumption. In spite of all these changes, it was found in a case study of village Banhera Tanda in the district of Hardwar of Uttar Pradesh that the intensity of cropping decreases with the increase in

distance from the settlement, provided the physical environment and living standard of the farmers are the same.

In some of the developing countries like India, Pakistan and Mexico, the introduction of HYV has disturbed the application of von Thunon Model. The fast development of means of transportation has made it possible to transport the perishable goods at long distances in short period of time. Thus, the model advocated by von Thunen is no longer operative in its original form.

Jonasson's Model

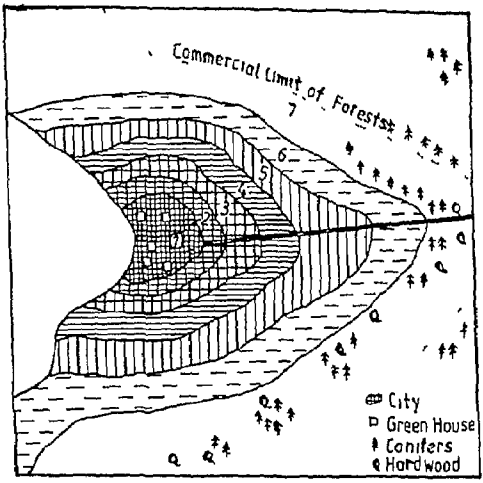
Olof Jonasson, the Swedish geographer, modified the von Thunen's model, relating to the economic rent of land in relation to market and means of transportations. The modified form of von Thunen's model devised by Jonasson is given in Figure 8.7. He applied this model to the agricultural landscape patterns of Europe in 1925. He observed that in Europe and North America, zones of agricultural land use were arranged about the industrial centres. In both the continents, i.e., Europe and North America, the most intensive development of agriculture is the hay and pastures region in which the industrial centres are situated. Around these pastures are arranged concentrically the succesive grades of land use—grain growing, pasturing and forestry. Jonasson advocated a model similar to the model of von Thunen, around a theoretical isolated city in Europe.

Jonasson found an identical pattern of distribution of zones on the Edwards Plateau in Texas.

Jonasson's model was adopted by Valkenburg in 1952 when he prepared a map of the intensity of agriculture in Europe (Fig.8.8). The map of Europe produced by Valkenburg shows the productivity of the land per acre on the basis of eight very widely raised crops, viz , wheat, rye, barley, oats, corn, potatoes, sugarbeet and hay. For each crop, the average yield per acre for Europe as whole is taken as an index of 100 and the specific yield in each country is calculated accordingly. The outstanding fact is that the Netherlands and Belgium lead in intensity, with Denmark, Switzerland and England closely approaching them. The application of fertilizers in such areas is a major factor, as are the selection of seeds and careful crop rotation. If one regards the major market of Europe for agricultural prod-

Figure 8.7

Zones of Production about a Theoretical Isolated City in Europe According to O Jonasson



Zone 1 The city itself and immediate environs, green house floriculture

Zone 2 Truck products, fruits, potatoes and tobacco (and horses)

Zone 3 Dairy products, cattle for beef, sheep for mutton veal forage, oats, flax and fibres

Zone 4 General farming, grain hay, livestock

Zone 5 Bread cereals and flax for oil

Zone 6 Cattle (beef and range), horses (range), and sheep (range), salt, smoked, refrigerated, and canned meats, bones tallow and hides

Zone 7 The outermost peripheral area, forests

ucts as northeast France, the Netherland, Belgium, southeast England, north Germany and Denmark, then von Thunen's model seems to be applicable on a continental scale However, it is not as simple as this, since to mention just one factor, the periphery of Europe has much less useful agricultural land (the Alps, Pyrenees and Apennines)

The pioneer model of land use and crop theory advocated by von

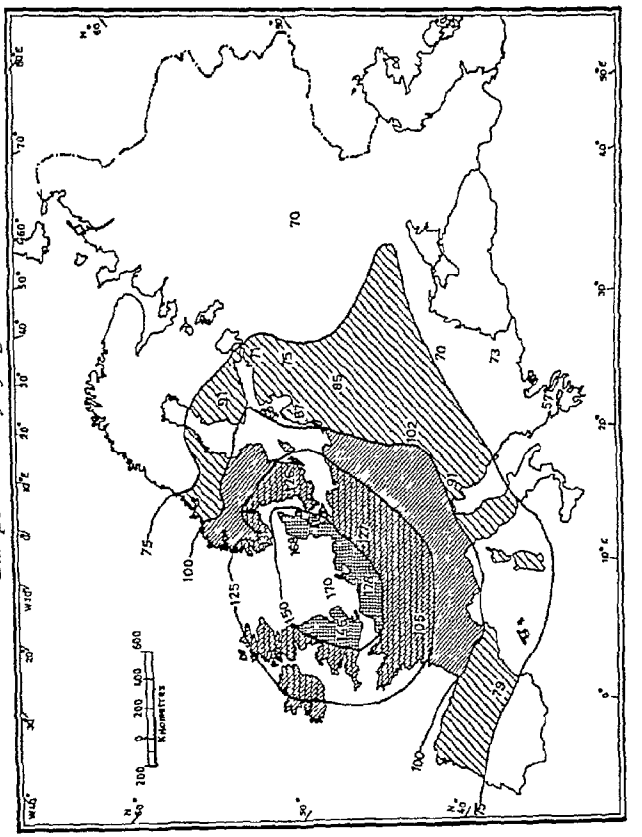


Figure 8.8
Europe · Intensity of Agriculture

Thunen is simple and valid in some of the underdeveloped countries of the tropical world, but the fact is that this model does not exist in reality. The relative costs of transport have changed and many of the assumptions of von Thunen are not found in the real world.

The main criticism against von Thunen model is that it is based on unrealistic assumptions. The modern transport system deviates from the principle of constant tonne-mile cost. In the modern system of transport, for example, larger the distance, lower is the transport costs per tonne/kilometre. The weakness in his model lay in his neglect of the changing demand functions of agricultural products and the fact is that this generalization was based on a micro study of the phenomenon. Moreover, no estate has an isolated entity in the fast changing world in which distances have been reduced appreciably by the swift means of transportation, and consequently, the world markets are shrinking at a faster rate. The farmers have international markets to dispose of their commodities. von Thunen's dogmatic approach to the rural-urban continuum and bias in favour of large towns was equally unrealistic, even though he recognized in his latter writings that diseconomies of scale set in, after a town attained a certain size and that the increasing distance between towns, a corollary of their growth in size is a drawback for the country.

Man with the help of new technological developments has changed the use of natural resources and new resources have come into existence. For example, timber is now little used for fuel in the developed countries of Europe and America, so it no longer commands such proximity to the market. London and Paris get milk in refrigerated containers and canned cheese and butter from New Zealand and Argentina. The improvements in transport and storage technology have lowered transport costs, so production is possible much further from the market.

Moreover, the impression that von Thunen's Model of concentric agricultural zones gives is that these rings were solely determined by intensity. It is somewhat misleading even though his scheme considered predominantly of systems of rising intensity towards as central market (Hall, 1966). The economic rent was assumed by von Thunen as to be the product of transport costs.

The assumption of von Thunen about the determination of rent

was not correct. The assumption that the farmers act as economic men is also a wrong assumption. In the real world farmers always do not behave as economic men. They do not act as rational men. They are often independent of one another. In many countries, the cooperative farming and collective farming have developed since von Thunen's days. The transport agencies in many areas of specialized agriculture transport the produce at a cheaper rate to the distant markets, which modifies the locational rent and the land use patterns.

The farmers, in spite of their long experience as farmers, cannot behave as an economic men as they do not know what will be the weather conditions next season. The farming, especially in the developing countries, is largely a gamble on weather. Within one agricultural season, different farmers sow different crops within an agroclimatic micro region and the selection of crops is mostly done by the farmer on the basis of his intelligence and experience.

Many criticisms have been put forward by the experts of land use about the crop intensity theory of von Thunen, but while criticizing the model, it should be kept in mind that the model was postulated in 1826 when the means of transportation and communication were not so well developed and isolated estates were found in many parts of the world.

The work of von Thunen is useful in two ways. First, it focuses attention on economic factors, particularly transport costs and distance to market, contrary to the earlier geographers' works who were subordinated by the factors of physical environment when attempting to land use patterns. Secondly, it attempted the concept of locational rent theory. This concept has great significance in both the rural land use and urban land use studies. Moreover, the assumptions of von Thunen led to more researches in the field of locational rent theories, cropping intensity and land use patterns. It can, therefore, be said that for geographers, von Thunen's work, with all its limitations, still provides a useful framework for organizing village and farm studies.

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9 Food, Nutrition and Health

People generally eat what they grow or the food they find in their surroundings. The geographic variations, like geoclimatic and pedological conditions, influence the growth of crops and domestication of animals. It is because of the variations in the geoecological conditions and sociocultural milieu that the food habits of the people differ in the different parts of the world. For example, the Semangs of Malaysia and Mesais of East Africa eat berries, nuts, grains, vegetables, flesh and blood of cattle, while the Eskimos of the Tundra region almost exclusively depend on whale, seal, warul and reindeer for their food requirements. The Europeans and Americans generally eat mutton, beef, pork, poultry, milk and milk products, wheat, potatoes, vegetables and fruits, while the Polynesian consume fish, coconut, vegetables and coarse grains. The Bushmen living in the inhospitable environment of Kalahari desert are basically hunters and eat roots, berries, grubs, insects, tortoises, frogs, lizards and ants. In India, the Punjabis eat cereals (wheat, rice), pulses, vegetables, milk, poultry, fruits, etc., while the Bengalis relish rice with fish. Milk and milk products are taboos among the Khasis and Jaintia tribes of Meghalaya, while pork is forbidden among Muslims and beef is prohibited among the Hindus.

Despite great diversity in the food, cereals furnish the staple diet of most of the people of the world. The cereals mostly used in various parts of the world are rice and wheat. Corn (maize) is next, followed by rye, barley and buckwheat. At least 60 per cent of the man-

kind's diet is made up of grams (rice, wheat, maize, etc.) and the remaining 40 per cent must be divided among the legumes, sugars, vegetables, fruits, nuts, oil products and meats. The people of Asia largely subsist on rice and about 50 per cent of the world population eats very little meat.

The major quantity of world's food is produced in those areas where it is consumed or people concentrate in the areas where food is being produced. Nevertheless, complete self-sufficiency in food on national lines does not exist anywhere and interdependence on a world basis is increasing. For example, Indonesia and Philippines must import rice. Brazil and Cuba must import wheat. A large part of the temperate zone is dependent on USA, Canada, Australia, Argentina for its wheat. Vietnam and Myanmar (Burma) export rice; Cuba, India and Java export sugar; Uruguay, New Zealand, Australia and Argentina export meat; and the Scandinavian countries (Denmark, Finland, Norway, Sweden) export milk and milk products.

In general, it is important to remember that the agricultural system of a nation is an integral part of its socioeconomic system, and that it often places constraints on how much food is produced. For example, it is often overlooked in discussions of the world food problem that farmers, like corporate executives, university professors and business organizers, expect economic rewards from their labour and, therefore, they will not grow food to sell for less than it costs to grow it. It is only in the areas of subsistence agriculture where the farmers are compelled by the family food requirements to bring more area under cereal crops.

Major Food Crops

During the period of last about 10 thousand years when man started agriculture, some 80 species of plants have been domesticated as opposed to only about two dozen kinds of animals. Over the centuries, most of them have been improved by selective breeding and/or by hybridization. But, in spite of diversity of available food plants, a relatively small number of crops supply the great bulk of world's food. Rice, wheat and corn (maize) are the three major cereals covering about 60 per cent of the harvested land of the world. Rice and wheat together provide roughly 40 per cent of humanity's food energy. Altogether, cereals provide over 50 per cent of the calories and

half of the protein consumed by the human population.

Rice is the most important staple food crop of the world. In 1994-95 the total world production of unhusked wheat was 975 million tonnes. Over 90 per cent of world's rice production is consumed in Asia where about 3 billion people or 55 per cent of the total population of the world lives.

Rice occupies about 148 million hectares of the cultivated land globally, of which 133 million hectares are in Asia. Rice is the staple food for over 40 per cent of the world's population. India has the world's largest area under rice (42 million hectares). In all there are 11 main rice growing countries in the world. The Republic of China grows about 30 per cent of the world's rice, India contributes about one-fourth, while Indonesia, Thailand, Japan, Myanmar (Burma), Philippines, Bangladesh, Brazil, Malaysia, Pakistan and Sri Lanka are the other leading producers of rice in the world.

Wheat is the second most important staple food. In 1994-95 about 750 thousand tonnes of wheat was produced in the world. Wheat is grown mostly in areas where winters are cool and moist and summers hot and dry. The United States of America, Canada, Australia, Argentina, China, France, India, Pakistan and West European countries are its major producers.

Corn is the third important cereal crop. Its production in 1994-95 was about 280 thousand tonnes. Corn cultivation requires long, warm and moist summers. Over 45 per cent of the world's supply of maize comes from USA. It is a staple food in the countries of tropical Africa and tropical Latin America.

In addition to rice, wheat and maize, barley, oats, rye, millets and sorghum provide nourishment to over 10 per cent of the total population of the world. These grains together with maize are commonly known as 'coarse grains' while wheat and rice are referred as 'small grains'.

There are many roots and stems eaten by mankind. Nearly 220 thousand tonnes of potatoes are grown but the water content of potato (75%) is so high that the food value of the total harvest is considerably less to that of rice, wheat and maize. It, however, gives higher yield per hectare. The crop of potato is well adapted to cool climates. About 33 per cent of the world's potato production comes from Rus-

sia and Central Asian Republics (Kazakistan, Kirgistan, Tajkistan, Turkmenistan, Uzabaikistan); Poland and China produce about 16 per cent and 12 per cent respectively of the total production of potatoes. The United States, Germany, France, India, Pakistan and East European countries are the other important producers of potatoes.

Legumes (peas, pulses, beans, peanuts, soyabeans and several forage crops) are very rich in protein content. The production of legumes is, however, low as compared to wheat, rice and maize. For the human population, legumes provide about 20 per cent of the protein supply worldwide. All the leguminous crops have the ability to fix nitrogen in the soil from the atmosphere. In fact, they serve as fertilizers (green manure).

The leguminous crops (soyabean, peanuts, groundnuts) are grown mainly for use as oil sources and livestock feed. These two crops account for about 66 per cent of the world's legume production. The protein content of soyabean is three times higher to that of wheat. Both soyabean oil and peanut are used for making margarine (butter etc.) and are also used in various industrial processes. Production of soyabean is mainly concentrated in USA, China, Brazil and India. The main producers of peanut are India, China, Pakistan and tropical African countries.

The remaining legumes are known as pulses. The pulses include black gram, green gram, red gram, lentil, pegion pea, cow pea, peas, limabeans, stringbeans, etc. Being the richest plant sources of protein, they provide a significant element in the human diet, especially to the people of developing and poor countries.

The production of pulses, unfortunately, has not increased since the middle of the present century. In the developed countries they have been replaced in part by increased consumption of meat and dairy products but in the areas of rapid growth of population (developing countries) the declining trend in the production of pulses has resulted into considerable reduction in per capita supplies of protein. Since the gap has mainly been filled by grains, the probable result is a deterioration of protein levels in diets—both in quantity and quality. In India, Pakistan, China, Mexico, Egypt, Iran, Turkey, etc., the area of pulses has been captured by rice and wheat which give more yield per unit area.

Apart from cereals and legumes, a vast variety of other plants is cultivated for human consumption. Cassava, sweet potatoes, taro, yams (all root crops) supply food energy to millions of people in the world, especially to the people of tropical Africa and Central America. The people of these regions subsisting on starchy foods are suffering from protein deficiency. The roots of sugarbeet plant and the stems of sugarcane plant (a grass) supply sugar to people around the world. The roots, stems, fruits, berries and leaves of numerous other plants are the important sources of energy, vitamins and minerals in human bodies. There are numerous crops used as forages—foods for domestic animals. For example, alfafa, called *lucern* in Europe and *barseem* in Egypt, India, Pakistan, etc., is among the most nutritious of all forage crops and is specially rich in protein. Some other legumes, e.g., cloves, grown as forage, are great variety of grasses.

Food from Animals

In many cultures, domesticated animals is a source of high quality protein. They are, of course, valued for other roles as well, especially in less developed countries where traditional techniques of agriculture still prevail. There are large farm animals (cattle, horses, buffaloes) who are highly valued as draught animals and as transport. The dung of all livestock is valued everywhere as an important source of fertilizer and in some regions as fuel and building plaster.

There are only nine species (cattle, pigs, sheep, goats, buffaloes, chickens, ducks, geese and turkeys) which account for nearly 96 per cent of the world's production of protein from domesticated animals. Beef and pork together account for about 90 per cent of meat production. Cows produce more than 90 per cent of the milk consumed, buffaloes about 4 per cent, and goats and sheep the remainder.

Animal husbandry is mainly concentrated in the temperate regions of the world. The animals of temperate regions produce more milk, meat and eggs. The high temperatures and high relative humidity of the tropical countries affect their production adversely. High temperature and humidity often provide ideal conditions for parasites and carriers of disease. For example, in Africa, tse-tse flies carry a serious disease, *nagana* (caused by organism called trypanosomes), which make cattle herding impossible (Fig.9.1).

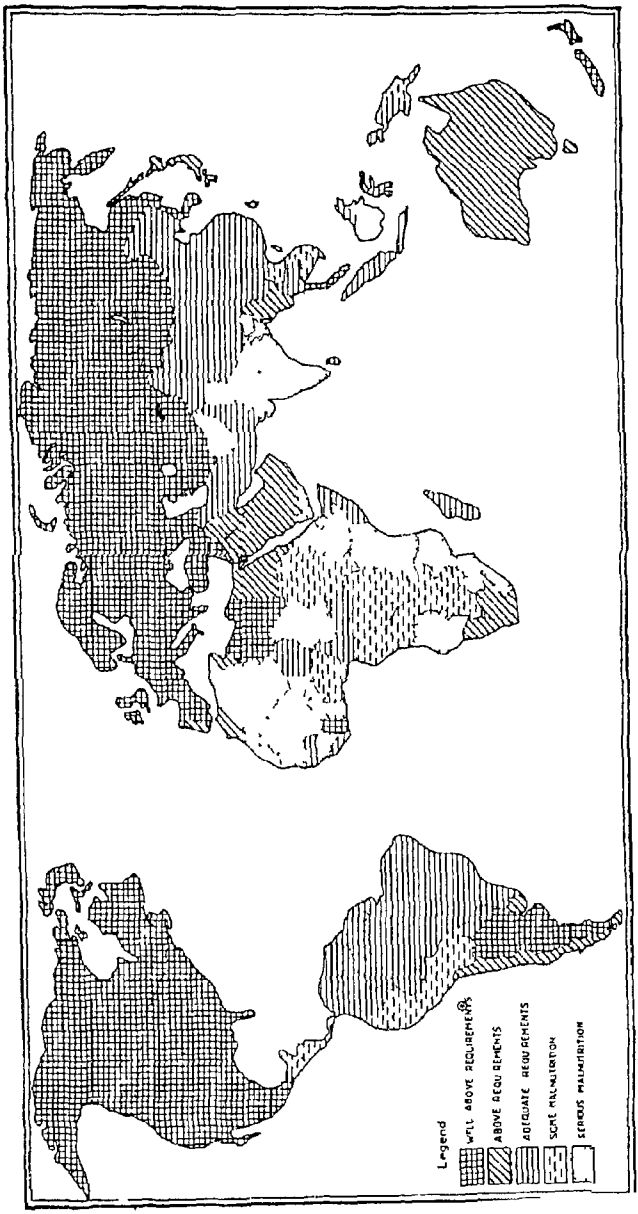


Figure 9.1
World Food and Nutrition

In some of the African countries animals are regularly tapped for blood as well as milk. Cattle provide their owners with wealth and prestige, are used ceremonially, and have aesthetic value.

In India, there is a large population of 'sacred cattle', so called because of the Hindu taboo against slaughter. In urban areas of India, most of the cattle feed on forage and waste vegetation that are not human foods: they generally do not compete with people for food. The cattle do supply milk and above all they supply power, specially in countries like India. They also supply dung, which serves as the main cooking fuel of India, and which is also used as manure and as plaster in houses.

Distributional Patterns of Food and Nutrition

The availability of food and nutrition is highly unevenly distributed in the world. In fact, there is significant nutritional gap between developed and developing nations. According to the United Nations Food and Agriculture Organization (FAO), some 3100 calories per head per day on the average were available in the developed countries. Contrary to this, in the developing countries, the per head per day availability of calories was 2200. An average of about 100 grams of protein were available in the developed countries as against about 50 grams in the developing countries. The average daily energy and protein supply have been shown in Table 9.1.

Table 9.1

Average Daily Energy and Protein Supply by Region

Region	*Available calories per head per day*	*Available protein per head per day*	*Energy as per cent of requirement*
Western Europe	3050	90	123
North America	3125	92	126
Oceania	3220	93	125
Eastern Europe and Russia	2990	85	120
Africa	2120	52	92
Far East	2050	55	94
Latin America	2400	60	105
Near East World	2200	60	102
World	2380	65	104

Source· U.N.O. Assessment.

It may be seen from Table 9.1 that the people of Oceania are having the highest consumption of calories and protein. Contrary to this, the nutritional and protein levels are very low in the African and Asian countries followed by the Latin American countries.

Although individual needs for calories vary accordingly to age, sex, body size and activity, the FAO has established standard 'reference' body weights and standard daily per capita calories requirements for estimating a population's caloric food needs. Children's needs, which are higher than those of adults in proportion to their body weights, are standardized according to weight groups. For adults, allowances are also made for pregnancies and differences in age and sex.

On the average, men need more calories than women. Even with these considerations taken into account, however, it is clear that there are many countries whose populations are badly underfed. For example, the daily caloric intake in the United States, Canada, Australia and New Zealand exceeds 3100 per person, but in India, Philippines, Ethiopia, Ecuador, etc., the daily average in below 2360 calories. This figure 2360 calories is given as the minimum daily requirement by the FAO. Actually, about 50 per cent of the people of the world survive on fewer calories than this.

The situation would not be so bad if the people who must survive on too little food could at least have a balanced diet, but they are not so fortunate. The countries where there is low caloric intake are also the countries where protein is in short supply. Recent studies have indicated that the first six months of life are critical in this respect: inadequate protein intake can damage brain and body for life. Furthermore, the food sources that are richest in proteins—meat, beef, fish, and dairy products—are all too often in short supply where they are most needed. In India, among the Hindus, taking meat and beef is a taboo. Consequently, they have to depend on milk products and pulses for their protein requirements.

The existing scenario of caloric intake may be summarized as under:

1. Adequate nutrition requires sufficient calories and a balanced diet. More than half of the world's population suffers from

nutritional deficiency.

2. People in tropical Africa, Central South America, South Asia and Southeast Asia are most severely malnourished.
3. Regional hunger is a national as well as global phenomenon. Even in better fed regions, pockets of malnutrition persist.
4. The regional distribution of hunger relates to environmental and social conditions, often in combination.
5. Hunger and disease are closely related. Poor nutrition increases susceptibility.
6. The regional distribution of diseases and their diffusion depend on environmental conditions and levels of development.
7. Infectious diseases and their vectors severely afflict peoples in equatorial and tropical regions.
8. Facilities of treatment are inadequate for hundreds of millions of the developing countries.

Causes and Spatial Patterns of Hunger

As discussed at the outset the production and distribution of food crops is not uniform in the different parts of the world. Consequently, there are surplus and deficit areas of food. Even in the food surplus regions, there are chances of crop failures because of physical and/or socioeconomic factors. The main causes of hunger and its spatial distribution have been discussed briefly in this section.

Hunger, deprivation and starvation have been recorded throughout the history of mankind. During the medieval periods there had been numerous droughts and deluges which resulted into crops failure causing miseries and deaths to humanity. In the absence of developed means of communications during the medieval period, the loss of human and animal life was enormous. The situation has now changed subtly. The modern means of communication and transportation provide ready relief to the areas adversely affected by natural calamities. There are, however, physical and sociopolitical reasons which may accentuate the miseries of the poor peoples, particularly those living in the backward areas of the developing countries. The crops failure, weather fluctuations, non-availability of energy, non-availability of alternate sources of conventional food and the sociopolitical constraints may be said as the main causes of hunger and

undernourishment in the world.

Harvest Failure

Failure of crops in an agricultural season and consecutive for several years in the main cause of hunger. In the 1970s the repeated failure of grain crops was the most ominous factor that contributed to food crisis and hunger in the various parts of the world. A similar situation occurred in the 1980s when crop failures were recorded in India, Pakistan, China, Russia, Central Asia, USA, Sahel (south of Sahara desert) and many other parts of the developing countries. These failures were related to the environmental changes because weather was erratic over the greater parts of the earth.

In India, owing to the failure of monsoon, the underground water table got lowered and the drought reduced the availability of irrigation water in 1986 to 1988 in the states of Punjab, Haryana, western Uttar Pradesh, Rajasthan, Madhya Pradesh and Maharashtra. Similarly, a severe summer drought affected the United States and South Africa in 1980, and its effect on wheat harvest was strong. The severity of climate and deficiencies of moisture often result into crop failures in Ukraine, Volga region and the East European countries.

Climatic Change

Throughout the period of written human history the direct and indirect evidences show that climate has changed. There had occurred droughts, deluges and severe storms owing to the climatic change. Consequently, there had been crop failures, loss of life and crops. It is well known that the Sahara and Southwest Asian countries were more wet only about one thousand years ago. In recent years, the Sahel region of Africa and Ethiopia recorded some of the severe droughts which have been attributed to climatic change by some of the climatologists. At the occurrence of droughts streams failed to flow, oases and wells dried up and countless people wandered into the encroaching desert to die. Some were sustained by emergency relief but others succumbed to epidemic disease.

Undependable weather has always affected adversely farming everywhere. In many parts of India, agriculture is often been called as 'a gamble on monsoon'. Other abnormal weather phenomena, such as excessive or ill-timed rain, unseasonable heat or cold, also af-

fected yields negatively.

Costly Inputs

The modern agriculture is highly dependent on chemical fertilizers, insecticides and pesticides. These inputs are made of petroleum—a costly source of energy. The farmers of the developing countries in general and the poor farmers in particular are not in a position to apply the required quantities of these costly inputs. Moreover, the non-availability of low cost energy puts a constraint on irrigation pumps that are run by gasoline. The high yielding varieties (HYV) of wheat and rice are performing very well in the areas where controlled irrigation and low cost energy in the form of chemical fertilizer are available.

The Failure of Alternate Sources

One major hope for the alleviation of world malnutrition has long focused on the oceans as an inexhaustible source of a direly needed commodity—protein. Unfortunately, the notion that vastly greater amounts of food can be extracted from the sea in the near future is an allusion. Biologists have carefully measured the riches of the seas, considered the means of harvesting them, and have found them wanting as a solution of the world food problem. According to J.H. Ryther, "the open sea—90 per cent of the ocean and nearly three-fourths of the earth's surface—is essentially a biological desert. It produces a negligible fraction of the world's fish catch at present and has little or no potential for yielding more in the future". Thus, the prospects of increasing the yield of food from the sea to support human life are decidely not bright.

The existing traditional food supply needs to be enhanced to meet the growing food demand of the rapidly increasing population. Some of the experts are optimistic emphasizing on 'synthetic' protein supplements. The synthetic protein, if it is developed to popularize, would be too costly and beyond the purchasing capacity of masses of the developing countries.

Inadequacy of Social Reform

Though most of the people are concerned about the growth of population, the population, particularly in the developing countries, is

growing at an unparallel rate. The failure of population control, the absence of land reform where it is most needed, the continued inadequacy of distribution network, and the faith of the many people that millions on the earth have to starve and nothing can be done about it. Thus the inadequacy of social reforms has aggravated the food situation in the developing countries.

Social Taboos about Diet

In some of the religious and ethnic groups there are taboos about food and food habits. These taboos come in the way of improving their diets. All the major religions of the world have prohibited the eating of certain foods, either on particular days or permanently. On fast days, the Christian faith prohibit the consumption of fish, meat and animal products. Judaism classifies a substantial number of animals, including the pig, camel and certain species of fish as unclean. Islam prohibits the eating of pork and the meat of certain animals and birds. Hindu religion proscribes the eating of beef, meat, fish, poultry and even eggs. Buddhism discourages the taking of animal life for purposes of routine nutrition. Similarly, various others societies do not like to eat fish, eggs or other potentially nourishing foods. The social taboos and religious constraints are also the cause of malnutrition and undernaurishment in the world.

Slow Pace of Innovations Diffusion in Agriculture

The farmers of the developing countries are conservative, less progressive and many a times do not change their cropping patterns by adoption of new seeds and new agricultural technology. In many of the developing countries where there is scarcity of food, cash crops continue to occupy the good quality of land. For example, jute in Bangladesh, tea in Assam (India), cotton in Egypt, *qaat* in Yeman, peanuts in Senegal, coffee in Angola, and tobacco in Zimbabwe occupy the highly productive lands which could have been devoted to the staple food crops. Moreover, the foreign exchange earned by selling the cash crops is generally not utilized for the purchase of food. Such foreign exchange in spent on military equipment and luxury goods. Unfortunately, fruits, vegetables and fish from the developing countries are being exported to the developed countries that already enjoyed a wide range of such products. The African, Central Ameri-

can and Asian produce are being sold in European markets. Fish caught off South American shores is sold in European markets. This is known as the 'protein flight'. On the flow map of world nutrition, the flight of protein from the underdeveloped countries is one of the harsh realities.

Eradication of Hunger

There are interregional and intraregional disparities in the levels of food and nutrition. While the peoples of developed countries are overconsuming food, the masses of the developing countries are in the grip of hunger, starvation and malnutrition. A holistic approach is required to minimize the severity of hunger. The developed food producing countries must organize to meet regional emergencies. The developing countries must spend their resources on agriculture and family planning, and not on nuclear bombs and military hardwares. In other words, global cooperation on the food problem requires sacrifices. Unfortunately, all the countries are not willing to do sacrifices.

The food problem needs to be attacked at two fronts, i.e., (i) reduction in population growth rate, and (ii) the people of rich and developed surplus producing countries to reduce their food consumption to the required level.

The developed countries like USA, Canada and Australia should enhance the production of cereal crops. For the farmers of the developing countries cheap fertilizers should be made available to get better returns from the HYV of wheat and rice. The developing countries can help themselves by reducing the expenditure on arms and by diverting the freed funds to food production.

The food distribution system in the developing countries needs to be strengthened. Food storage facilities must be restored and steps should be taken to protect stored grains from rodents. A long range population policy should be evolved in the developing countries, because unless the population explosion is contained, no effort to remove hunger will be sufficient. The population control will require rapid economic growth, research and the implementation of strict population policies. The following steps may go a long way in overcoming the problems of hunger and malnutrition:

Population Policies

The main cause of poverty and hunger is the fast growth of population. The control of population growth, therefore, should get the top priority, particularly in the developing countries. It is always difficult to implement a strict population policy. China, Japan and South Korea are among the leading countries that have controlled the population growth significantly. In the South Asian, Central American and African countries the population policies have not been designed and implemented strictly as a result the population of these countries is multiplying after every thirty years. It shows that population control is least effective where the crisis is felt most strongly and what little progress is made annually is consumed by the additional mouths that must be fed.

Greater Agricultural Productivity

In the recent decades new areas and culturable wastes have been brought under cultivation to increase agricultural production. In the mid-sixties a major breakthrough in agriculture was made in the form of adoption of HYV of cereals. This development is also known as the Green Revolution in the developing countries. The production of wheat, rice, maize and millets increased substantially. Nevertheless, the Green Revolution could not eradicate hunger from the developing world. The HYV need heavy dozes of chemical fertilizers and adequate supply of water through controlled irrigation. These costly inputs are beyond the reach of marginal and small farmers of the Third World countries. There is a need to develop drought resistant crops which may be diffused in the areas of deficient rainfall.

Expansion of Agriculture in New Areas

At present, only 10 per cent of the total area of the land surface is under cultivation. Some experts opine that the present cultivated area could be tripled. The possibility of expansion of agriculture is either in the tropical rain forests or in the areas of deficient rainfall. The indiscriminate felling of trees may be catastrophic for the humanity and may cause serious ecological problems, while bringing new areas under cultivation in the semiarid and arid regions may be an expensive proposition. In fact, development of irrigation facilities in the areas of scanty rainfall requires enormous amount.

Land Reforms

It has been proved many times that farmers cultivate their own land more carefully and productively than someone else's land. It is, therefore, necessary to give the land to the cultivators. It has been found that wherever land reform measures have been taken, production of crops has gone up substantially. In order to maintain the fertility of the soil the farmers have to invest in farm management. A tenant farmer cannot take a decision about the development of fields. The need for land reform is nearly worldwide. Unfortunately, progress in this area is too much slow.

Search for Alternative Food

The hope that the oceans might provide an almost limitless supply of high-protein food has recently diminished. There are, however, limits to the ocean harvests, just as there are on land. It is urgently needed at the global level to protect the ocean resources while they are used. Until quite recently, only a few species of marine fauna were endangered by overfishing as whales. Now, however, radar equipped, machine driven vessels can secure such enormous hauls that there are already areas where such common fish as sardines, herring, salmon, tuna and cod are being depleted beyond the level of potential recovery. Larger fish eat smaller fish. When a whole region is cleared of small fish, larger fish can be expected to die out.

The oceans remain open to all countries. The countries that need protein most desperately or the technologically advanced countries which have floating factories and huge fleets playing all the oceans.

Aquaculture—the raising of fish in enclosures—is a great hope for alternative source of food. It has developed considerably in Japan. Now food scientists are trying to make food from grass, leaves and algae from the sea. These foods are, however, not relished by the people with rigid and conservative food habits.

The problem of hunger and malnutrition may also be minimized if the people change their food habits. Mass education, especially the female education, will also go a long way in overcoming the deficiencies of food and may eradicate hunger to a substantial extent. None of these efforts will bring the desired results unless a comprehensive programme is chalked out to check the growth of population,

to reduce the food consumption in rich societies, and to develop alternative sources of food and proteins.

Nutrition and Health

There is a close relationship between the availability and quality of food and health of the people. People who are inadequately fed are susceptible to many deficiency diseases. Hunger and malnutrition produce dangerous weaknesses in the body, and lower resistance to all kinds of disease organisms.

In the developed countries like New Zealand, Sweden, Norway and USA, where food is generally adequate and inspected for quality, and where drinking water is purified and treated, the disease of hunger and malnutrition are not major threats. Contrary to this, people in the developing countries suffer from many of the deficiency diseases. In fact, the regions of the world where malnutrition prevails are also the areas of poverty, inadequate medical services, inadequate sanitation and substandard housing. It is difficult, therefore, to discover the specific effects of malnutrition on people's susceptibility to disease, because so many factors are present at the same time. There is, however, little doubt about the effects of malnutrition on the growth and development of the body. Some of the deficiency diseases have been briefly described here-under:

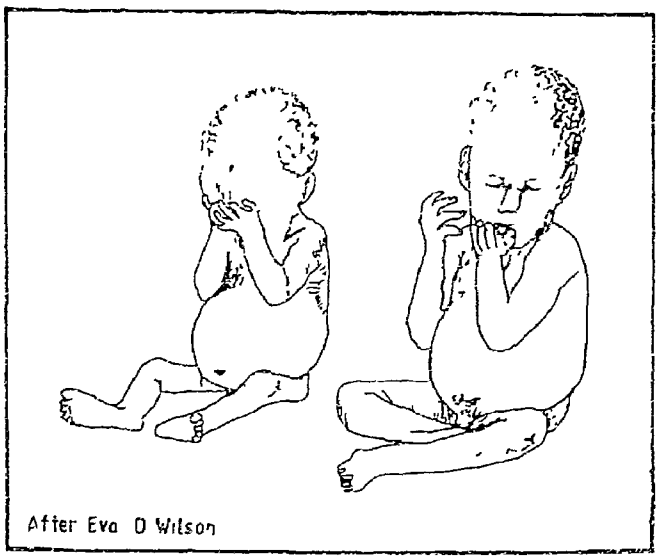
Marasmus

This is a disease commonly found in the developing countries. Marasmus is often been considered as a strong indicative of overall undernourishment. It is also referred to a disease occurring owing to the protein deficiency in children. It seems to be related to early weaning or to a failure in breast feeding, when inadequate substitutes for mother's milk are provided, and it often appears following a bout of diarrhoea or some other disease Most victims are babies below one year of age. The child with marasmum is very thin and wasted, with wrinkled skin and enormous eyes.

Kwashiorkor

This is a West African word that means the sickness the child develops when another baby is born. Kwashiorkor seems to be another form of protein-calorie starvation, resulting from inadequate supple-

Figure 9.2
Symptoms of Kwashiarkor



mentation for mother's milk after the age of six months or so. Sometimes it is predictable by weaning, when the child of one or two years is offered only starchy, bulky food to eat. In mild cases, the child's physical growth is retarded, the hair and skins are discoloured, and a pot belly develops. There is also a loss of appetite. When the disease is more acute, the discoloration is more pronounced, hair is loosely rooted and pulls out in tufts. legs and feet swell with fluids. digestive problem arise, and the child becomes markedly apathetic. After this stage is reached, death will follow unless medical care is quickly provided.

Xerophthalmia or Softening of Cornea

Vitamin A deficiency often accompanies protein malnutrition and show up in drying of eye membrane (xerophthalmia) or softening of the cornea (kerotomalacia), which soon leads to blindness if not treated. Supplementing protein deficient diet with high protein foods without adding vitamin A may cause a previously unsuspected defi-

ciency to appear in an acute form. The United Nations has estimated that more than 150000 children go blind each year in the Far East alone as a result of vitamin A deficiency.

Anaemia

Another prevalent form of malnutrition, especially in developing countries among women and small children, is anaemia, usually iron deficiency anaemia. Lack of protein, vitamin B or folic, acid can also play a part of anaemia. During pregnancy, a foetus absorbs from the mother's stored reserves a large supply of iron, which it needs during the months after birth (mother's milk contain very little iron). Successive pregnancies can very quickly lead to exhaustion of a mother's reserve supply, if her diet does not replenish it, the result is anaemia for both mother and child. The anaemia may increase the likelihood of stillbirth and premature birth.

Rickets

Ricket (softening of bones) is caused due to lack of Vitamin D or calcium or both. Vitamin D is synthesized in the skin when it is exposed to sunlight. Rickets first became a health problem for Europeans in smoky, congested cities during the Industrial Revolution, where children had only dim narrow alleys for playgrounds and often were kept indoors to work. It does exist more commonly in the cities and towns. It is also found in India, Pakistan and Bangladesh and the other Afro-Asian developing countries.

Goitre

Lack of dietary iodine causes goitre. According to one estimate more than 250 million people around the world suffer from goitre. Iodine is available from seafood and food grown in iodine-containing soils. Many regions of the world far inland from the sea have soils deficient in iodine. The deficiency in iodine also lead to dwarfing. But this can be entirely prevented simply by the use of iodized salt.

The problem of poverty, hungar, malnutrition and deficiancy disease can be solved by reducing the growth rate of population and enhencement in agricultural production. The developed countries should reduce consumerism to save more for those who are starving and undernourished.

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10 Indian Agriculture: Attributes and Rural Development Programmes

Agriculture occupies an important position in Indian economy. Its contribution to the national income in 1950-51 was up to 54 per cent which declined to about 30 per cent in 1994-95. It provides food, fodder and raw material and thus contributes to overall economic growth. Its good performance over the period of time helps in the generation of more employment, thereby reducing poverty, hunger, and malnutrition. The rapid economic development of any state or region without the development of its agriculture is almost impossible.

Agricultural output in India determines not only the per capita income of farm sector, it also influences the standard of living of rural population and the nutritional standard of the poor masses. The share of agriculture in the gross domestic product (GDP) in India is about 30 per cent as compared to about 27 per cent by the secondary sector.

Agrobased industries such as cotton and jute textiles, sugar, *vanaspati*, oils, *itr*(perfumes) and beverages like tea, coffee and cocoa are obtained from agriculture. Other industries based on agriculture are rice-husking, oil-crushing, handloom-weaving, rice-bran oil, cottonseed oil, coconut and copra oil. The workers employed in industry and infrastructural activities depend on agriculture for their food supplies. Moreover, agriculture provides large market for non-agricultural goods and services, and the market system interconnecting the rural and the urban areas narrows the chasm between them.

In India, agriculture and its allied activities provide a source of

livelihood to over 70 per cent of the total population. Artisans and menials in rural areas are also dependent on cultivators.

Transportation of agricultural commodities is the mainstay of railways and roads in India. International trade comprises agricultural products in the highest proportion. Storage and processing rely on agriculture. Trade in agricultural goods has played an important role in promoting economic development of our country. Agriculture and agrobased exports account for a substantial proportion of our total export earnings. Cotton and jute textiles, meat, beef, sugar, *vanaspati*, oils, tea, coffee, spices, wood, timber, lac, raisins, rice, cashew-kernel, tobacco, coconut, saffron, fresh and dry fruits (almond, walnut, apricot) are exported. These commodities still constitute over 16 per cent of the total export of India. The contribution of agriculture to the national income and its share in export has been presented in Table 10.1.

Table 10.1

India. Position of Agriculture in National Income and Total Export(1950-91)

(in per cent)

Year	*Contribution of agriculture to national income*	*Share of agriculture to total exports of India*
1950-51	54	52 5
1960-61	49	44 0
1970-71	47	37 5
1980-81	36	25 5
1990-91	31	16 5

Source: RBI Reports and Five Year Plans of India.

An examination of the above table makes it clear that the share of agriculture in the national income and in the total export is increasingly declining. Now agriculture contributes only about one-third to the national income as against 54 per cent in 1950-51. Similarly, the share of agricultural goods in export has declined from 52.5 per cent in 1950-51 to only 16.5 per cent in 1990-91.

Characteristics of Indian Agriculture

Indian economy as stated above hinges on agriculture. It not only

provides food to teeming millions, and fodder to millions of livestock, our agrobased industries are exclusively dependent on it for raw materials. It engages about 70 per cent of the workforce and still nearly three-fourth of the total population of the country is directly or indirectly dependent on it. Its share in the national income is about 31 per cent. The salient characteristics of Indian agriculture have been described in the fallowing headings:

Diversity in Agricultural Systems

India has a great number of agricultural systems as advocated by Whittlesey. Its large latitudinal sprawl and diverse climates have resulted into diverse agricultural systems. In different parts of the country, agriculture has conspicuously different traits appertaining to terrain, slope, temperature, rainfall, soil properties, size of holdings, technology, availability of irrigation, labour, infrastructure and marketing facilities. Consequently, there are macro and meso regional variations in agricultural topologies and agricultural systems. For example, the hill dwellers of northeast India are still practising *jhuming* (shifting cultivation) while in the upper Brahmaputra valley (Dibrugarh, Lakhimpur, Jaorhat) tea plantation is the dominant economic activity. The farmers of West Bengal and Bihar have the intensive subsistence (dominated by paddy crops) while the Punjabi and Haryanavi farmers are growing wheat and rice as the commercial crops. The Apatanis (a tribe of Arunachal Pradesh) have developed the paddy and fish culture while the Kashmiris devote their 'karewa' lands either to orchards (apple, almond, etc.) or to saffron. Cotton is the dominant crop in the black earth region while the farmers of Andhra coastal plain are concentrating on paddy and tobacco cultivation. Since each crop performs well under certain optimal geographical conditions the farmers of each region have adopted appropriate technologies for the cultivation of their crops. The Indian agricultural landscape thus has all sorts of agricultural systems ranging from nomadic herding and shifting cultivation to subsistence agriculture, plantation and commercial farming.

Dualistic in Character

In India agriculture is still a gamble on monsoon. Owing to the failure of monsoon crop failure occurs at an interval of three to five

years with monotonic regularity. The worst crop failures tend to spread over two to three consecutive years as it happened in 1962-64 and 1986-88 in Maharashtra, Madhya Pradesh, Uttar Pradesh, Haryana, Punjab and Rajasthan. In certain parts of the country like Marathwada (Aurangabad, Ahmadnagar, Bihar, Osmanabad) and Rajasthan (Bikaner, Jaisalmer, Barmer, Jodhpur) agriculture is almost annually vulnerable to drought. Contrary to this, the districts of Goalpara, Kamrup, Naogaon, Sibsagar, Barpeta (Assam), West Bengal, north Bihar, eastern Uttar Pradesh, coastal Orissa and Andhara Pradesh are severely affected by floods. In the areas where adequate means of irrigation and measures of flood control are not developed, the uncertainty factor has deprived cultivators of confidence in their better future.

Low Productivity

The agricultural productivity in India is low as compared to that of the developed countries. In most of the agroclimatic regions the per unit production is much below the national and international levels. The low levels of agricultural return may be attributed to absolute technology, small size of holdings, scattered fields and inequality in ownership. Most of the farmers are tradition bound, superstitious, uneducated, conservative and their risk taking capacity in very low. They are generally shy in the adoption of new technology and their poor economic condition is an impediment in the purchase of new seeds, fertilizers, good tools and technology and development of irrigation and other infrastructural facilities in their fields.

Diversity in Agricultural Technology

As stated earlier India has great diversity in agricultural systems. Each agriculture type and crop cultivation demands appropriate tools and technology. Consequently, there is great diversity in the technology used by the cultivators of the different parts of the country. For example, the shifting cultivators of Northeast India (Nagas, Lushais, Khasis, Apatanis) have a simple and rudimentary technology based on fire, *dao* and dibble-sticks, while the Bengali farmers plough their fields with wooden plough drawn by bullocks and/or buffaloes. In Mewar and Marwar (Rajasthan) camel is the draught animal while the progressive Jat farmers of Punjab use tractors and harvesters in

their farms. The use of chemical fertilizers, pesticides, weedicides, herbicides, rodenticides and fungicides also varies from one part of the country to another. The marketing, storage and processing facilities are unequally distributed in the country.

Absentee Landlords

Although the *zamindari* and the *raiyatwari* systems were abolished in the fifties in the country, there are still numerous absentee landlords in all parts of the country. According to one estimate about 50 per cent of the cultivated land of the country is under written or oral tenancy. The big farmers are invariably carrying on their agriculture with the help of agricultural labourers and sharecroppers. There is a tremendous increase in the number of agricultural workers and marginal cultivators who assist the big farmers in the cultivation of crops. These workers, marginal farmers and sharecroppers are often exploited by the landlords as usury is still in vogue.

Unity in Diversity

Indian agriculture displays unity in a number of respects, such as deficiency of nitrogen in all the total cultivated area; low productivity per unit area and per unit of labour in most regions; prevalence of backward traditional and outmoded techniques of production giving low returns; the relative scarcity of cultivated land; predominance of small farmers, great inequality in the ownership pattern of land, production by tenants and agricultural labourers under insecure conditions and hence risk aversion; vast seasonal and disguised unemployment, unprogressive agriculture, and the unsatisfactory socioeconomic environment of the rural sector in most parts of the country.

Disappearance of Traditional Social Institutions

The traditional institutions of mutual cooperation and reciprocal aid system are increasingly disappearing from the Indian rural society. The *jajmani* system prevalent in northern India since time immemorial has broken. In fact, agrarian relations are under severe strain and tense in several parts (e.g,. Bihar, Uttar Pradesh, Tamil Nadu). The village panchayats are subjected to caste politics and class antagonism. The common atmosphere in the village is one of mutual distrust which impedes group action needed for some kind of techno-

logical change, agricultural development and speedy transformation of the rural society.

Poor Linkage with Industrial Sector

Indian agriculture in most parts of the country has a very limited forward linkage with other activities. The links between agriculture and industry in terms of labour and material inputs are still very weak. The existing links are to provide raw materials for agrobased industries and a provider of raw materials to the industrial sector. The farmers are not in a position to dictate the terms in the fixation of price of agricultural commodities. His poor economic status comes in the way of developing strong linkages with industries.

Regional Inequalities in Food Production

Several states of the country are deficient in food production while a few are the surplus producers. The states of Punjab and Haryana are the surplus producers of wheat and rice, exporting these cereals to Uttar Pradesh, Bihar, West Bengal, Orissa, Madhya Pradesh, Andhra Pradesh, Rajasthan, Jammu & Kashmir, Gujarat, Maharashtra and Karnataka. Same is the case in the production of cash crops (sugarcane, jute, cotton, tea, coffee, spices, fruits), milk products, fisheries and forest products.

Fast Growth of Agricultural Workforce

Predominantly agricultural states like Assam, Bihar, Uttar Pradesh, Madhya Pradesh, Orissa, Andhra Pradesh, Himachal Pradesh and Rajasthan have generally unprogressive traditional agriculture. The abundant supply of labour has acted as a barrier to the improvement of agricultural productivity in them. The of total population dependent on agriculture has fallen marginally being only about 3 per cent. The growth of agricultural workforce in Punjab, Haryana and western Uttar Pradesh is insignificant. It is in these states where labourers are immigrating from the states of Bihar, eastern Uttar Pradesh, Rajasthan, Orissa, Himachal Pradesh and Jammu & Kashmir. In brief, taking country as a whole, about three-fourth of the workforce is directly or indirectly engaged in agriculture. The planning and development has had so far only a marginal impact on the percentage of total working population engaged in agriculture. Contrary to this, the

pressure on land is on the increasing side and many of the holdings are becoming economically unviable.

The process of transference of the labour force from agriculture to non-agriculture is insignificant. It is only in the relatively prosperous states like Punjab, Haryana, Maharashtra and Karnataka in which the workforce is being steadily transferred from agriculture to industrial and tertiary sectors. In Punjab and Haryana, the highly advanced technology like harvest combines and tractors has been deployed by the rich and big farmers. This has resulted into displacement of local labour force from the traditional employment which has migrated to the neighbouring towns and distant metropolitan cities. Shortage of workforce at the period of peak labour demand (sowing and harvesting of crops) has increasingly been felt by the farmers of Punjab, Haryana, western Uttar Pradesh, etc.

Environmental Degradation

Population growth and need for foreign exchange have compelled the Indian farmers to intensify their agriculture. While the production of cereal crops has gone up, the intensification of agriculture has also brought about environmental degradation. The impact of agricultural growth is being increasingly felt in the arid, semiarid, humid rain forest regions and mountainous areas. There is encroachment of agriculture into the pastures, forests and hilly tracts. The major environmental changes that have occurred are soil erosion, desertification, waterlogging and salinization The burning of forests for *jhum* fields and deforestation in the rainforest regions is the main agent of environmental change and while it has obvious localized effects, especially in relation to a soil erosion and soil degradation, there is growing concern that such large scale destruction of biomass may have implications for climatic change. Deforestation in the Himalayas and other mountains for the development of fields has caused accelerated soil erosion as well as water management problems for down slope, piedmont and deltaic region.

The adoption of HYV and overemphasis on the cultivation of rice and wheat in the semiarid areas with the help of irrigation and chemical fertilizers have changed the chemical properties of the soils. The new rotation of crops, the wheat and rice crop combination and the application of heavy dozes of NPK have depleted the soil fer-

tility to the extent that they are rapidly losing their resilient characteristics. Consequently, the area of saline and alkaline formations is increasing, especially in the Sutlej-Ganga plain. The problem of waterlogging is worsening in the Ganganagar, Jaisalmer, Jodhpur and Barmer districts of Rajasthan which are under the Indira Gandhi Canal command. The waterlogged pathces have become the ideal breeding grounds for mosquitoes. The outburst of malaria in October and November 1994 and in February and March 1995 in the arid and semiarid districts of Rajasthan testifies the fact that uncontrolled canal irrigation in the region is a health hazard.

The adverse effect of heavy doses of chemical fertilizers has been felt by the farmers of those regions in which wheat and rice or wheat-rice-sugercane combination is dominating the crop land use. The farmers of Punjab, Haryana and western Uttar Pradesh opine that the soil has become hungry and every year they have to apply more fertilizers, insecticides and water to get a satisfactory return from their fields. There are numerous other environmental problems emerging out of the agricultural development. In general, the degraded environment contributes to stress and ill-health. Air and water pollution directly affect health, which, in turn, affects the enjoyment and pleasure of life and the ability of labour to support the socioeconomic process.

Undoubtedly, agriculture over the greater parts of the country still works as a shock-absorber for seasonal, frictional and technological unemployment generated in the non-agricultural sectors. Its productivity is much below that of the developed countries (USA, Germany, Japan, etc.). There are regional and intra-regional variations in its efficiency. A package programme needs to be designed and implemented to overcome the specific problems of each micro and meso region and to enhance production per unit area of all the crops. Care is to be taken that the strategy for agricultural development should be ecofriendly which many help in maintaining the environment in sound health. Such steps will go a long way in making our agro-ecosystems more productive, less fragile and more sustainable.

Rural Development in India: Policy and Programme

After Independence the government of India paid especial attention

to rural development as over 70 per cent of our population is living in the villages. Consequently, a series of programmes have been designed and implemented since then. The various policies initiated during the Five Year Plans have been presented briefly in the following paras.

First Five Year Plan (1951-56)

The First Five Year Plan was initiated with a resolve to reconstruct the country economically and socially. The immediate and ultimate objectives of the planned development programmes were to provide for a production and that too to initiate a process of integrated change, including change in the outlook of rural masses. Thus, increasing production and reducing the existing inequalities were the two main objectives of the First Plan.

The three main features of agricultural planning in the First Plan were:

(i) The objects of the plan was not to increase agricultural production alone, but to bring about all-round development in rural life.
(ii) The main emphasis was on long term projects; the full advantage of this planning was to be realized after a period of fifteen to twenty years.
(iii) Formulation and implementation of various schemes related to the agriculture, irrigation and power were assigned to the state government, while the central government was to coordinate and to provide general assistance.

Table 10.2

Rural Development Policy and Programmes: First Five Year Plan

Policy	*Programmes*	*Year*
Community Development	Bhoodan Movement	1951
as Method and National	Gramdan Movement	1952
Extension Services as	Community Development Programme	1952
the Agency	National Extension Service	1952

Source· The First Five Year Plan, Government of India.

Bhoodan Movement and Gramdan Movement

The Bhoodan Movement was started on 18 April 1952, under the leadership of Vinoba Bhave. Its aim was to acquire surplus land through donation from individual landowners and to distribute the acquired land among the landless families. During the same period various movements, viz., 'Gramdan' and 'Shramdan' related to the rural development were also started. The main shortcoming of these efforts was that they were made without any conceptually broad-based strategy. They were adhoc in nature and in the absence of proper coordination they failed in providing the required results.

Community Development Programme

Community development is the method and rural extension agency through which the five year plan seeks to initiate a process of transformation of the social and economic life of the villages. The Community Development Programme(CDP), launched in 1952, too had the same philosophy. The major concern in these rural development programmes was to induce people to participate in development activities aimed at utilizing the locally available resources for their betterment. Village roads, school buildings, Panchayat Ghars and drinking water wells were constructed with people's participation (*shramdan*) and the organizations of rural cooperatives were given special emphasis.

With the launching of the CDP in 1952 throughout the country an attempt was made to initiate a systematic Integrated Rural Development Programme (IRDP). The basic intention of the CDP was to serve the rural people and to reach as large number of them as possible. The concept of making single multipurpose functionary responsible for all rural development activities at the grassroots level, particularly in the field of agricultural development, was conceived and put into operation in order to meet the requirement of reaching the rural households, especially farming households, with an integrated package of services. Thus, for the first time, the idea of the village level workers (VLW) supported at the block level by a team of specialists in the field of agriculture, animal husbandry, cooperatives, panchayats, social education, public health, programme for women and children, etc., was implemented. Initially, the CDP was started

with approximately 55 rural development project located areas of various states in the country.

Extension Services

With the object of securing increased production and raising the standard of village life extension services were started. Extension has been termed as a continuous process designed to make the rural people aware of their problems, and to suggest them the ways and means by which related problems can be solved by them. It thus involves not only to educate the rural people in determining their problems but to suggest the method of solving these problems, and inspiring them towards positive action in doing so. It is, therefore, of the highest importance that for this task, right personnel with zeal and enthusiasm are selected, to ensure the implementation of various rural revelopment programmes. The qualities required are not only the ability to acquire knowledge but also dedication to the task of serving the rural people for their development and to find out the solutions for their problems.

Second Five Year Plan (1956-61)

The approach of the Second Five Year Plan was based on the concept of a socialistic pattern of society. The strategic objectives of the Second Plan were: (i) to increase the annual national income by 5 per cent; (ii) to provide additional employment to about 10 million persons; (iii) to promote rapid industrialization; and (iv) to bring about a more even distribution of income, wealth and power, thus helping the creation of socialistic pattern of society.

Panchayati Raj

Panchayati Raj was first introduced in Rajasthan and Andhra Pradesh in 1959. Out of 21 states, the three-tier system of panchayati raj, i.e., Zilla Parishad, Panchayat Samiti and Gram Panchayat, was existing only in nine states, namely, Andhra Pradesh, Bihar, Gujarat, Himachal Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. Both Bihar and Madhya Pradesh have enacted legislations for three-tier system of panchayati raj, while Bihar has introduced the three-tier system in eight out of the erstwhile 31 districts in the state. Madhya Pradesh, by this time, did not constitute the third

tier, i.e., Zilla Parishad.

Table 10.3

Rural Development Policy and Programmes: Second Five Year Plan

Policy	*Programmes*	*Year*
Cooperative farming; later, local participation	Khadi and Village Industries Programme.	1957
	Village Housing Projects Scheme	1957
	Multipurpose Tribal Development Blocks Programme	1959
	Panchayati Raj	1959
	Package Programme	1960
	Intensive Agricultural District Programme	1960

Source The Second Five Year Plan, Government of India.

Village Panchayat has been an age-old institution in rural India deriving its power from the customary laws and local conditions. The set up of panchayati raj institutions(PRIs) as statutory organization, however, is of recent origin. This system was conceived as a process of democratic decentralization by the Balwant Rai Mehta Study Team which made its recommendations in the year 1957.

Package Programme

A package programme was worked out in 1960 for improving the agricultural practices in selected districts through the use of improved seeds, fertilizers, agricultural implements, etc., and the package of agro-services with the provision for competent technical advice, provision for credit and production supplies, storage, and to a limited extent development of roads.

Intensive Agricultural District Programme

The Intensive Agricultural District Programme(IADP), popularly known as the Package Programme, represents a significant departure in an approach from the CDP in that it employed the concentration principle in deploying resources as opposed to the equity criterion used in the CDP. Its basic premise was that India need to organize its agricultural production with enough resources to make it effective. The IADP experienced rough weather and hard going during the First Plan; its basic premise of concentration of resources in better

agricultural areas continued to be challenged. As its immediate goal the IADP sought to achieve rapid increases in agricultural production through a concentration of financial, technical, extension and administrative resources.

In the long term its aim was to achieve a self-generating breakthrough in productivity and to raise the production potential by stimulating the human and physical processes of change. The programme was also intended to provide lessons for extending such intensified agricultural production programmes to other areas.

Third Five Year Plan (1961-66)

The Third Five Year Plan reiterated that the development of agriculture, based on the utilization of the manpower resources of the countryside and the maximum use of local resources held a key to the rapid development of the country Crop yields were low and, therefore, with adequate irrigation, supplies of fertilizers on a large scale. improved seeds and implements, supply of credit through cooperatives, linked with production and marketing, education of farmers in better methods, mobilizing the rural community through community development organizations, and reform of land tenures and development of the agriculture economy on cooperative lines, large increases in levels of production could be achieved over relatively short periods.

Table 10.4

Rural Development Policy and Programmes Third Five Year Plan

Policy	*Programmes*	*Year*
Panchayati raj three-tier model of democratic decentralization	Rural Industrial Project Programme	1962
	Hill Area Development Programme	1962
	Tribal Area Development Programme	1962
	Applied Nutrition Programme	1962
	Intensive Agricultural Area Programme	1964
	Intensive Area Development Scheme	1965
	High Yielding Variety Programme	1965

Source The Third Five Year Plan, Government, of India

The Third Plan aimed to achieve the development of a diversified and efficient system of agriculture, including animal husbandry,

dairying, production of meat, fish, poultry, etc. Provision of a balanced and adequate diet for the entire population and the development of commercial crops to meet the increasing requirements of industry and export. Production of food grains, as well as cotton, oilseeds and other commercial crops had equal urgency.

To achieve the aims and objectives of the Third Plan various programmes and schemes were formulated.

Rural Industrial Projects Programme

The Rural Industrial Projects Programme was initiated as centrally sponsored scheme by the Planning Commission in 1962-63. On experimental basis rural industrial projects were started in selected districts so as to evolve appropriate methods and techniques for intensive development of village and small industries. This was followed by the Rural Artisan's Programme (1971-72) which sought to identify and develop local partisanship and provide support to the credit and marketing organizations.

The objective of Rural Industrial Projects Programme was clearly set out by the government in its industrial policy resolutions. The main thrust of the policy was on effective promotion of cottage and small industry widely dispersed in rural areas. The objectives of the programme were to solve the problems of unemployment, underemployment and poverty in order to achieve the goals of growth with social justice.

Hill Area Development Programme

It was recognized in the late sixties that the strategies of development adopted in the past had led to an uneven distribution of the benefits of development between geographical areas and also between socio-economic groups. In response to that realization certain area specific programmes were initiated during the Third Plan. After reviewing the programmes for drought prone areas and desert development, a third area specific programme was launched as a central sector scheme in the Fourth Plan was Hill Area Development Programme. Two central sector hill area development projects—one for Pauri Garhwal in Uttar Pradesh and second for Nungba subdivision of Manipur—were sanctioned during the Fourth Plan period which were continued during the Fifth Plan. Since the Fifth Plan, the concept of a

subplan has been introduced to ensure complementarity and linkages among the schemes formulated under the various sectors of the state plans and out of the central additive. The Hill Area Development Programme was continued during the Sixth Plan. The major emphasis of these projects has been on reducing the intraregional and interregional differences in the distribution of benefits from agricultural development. Each project is administered by an agency headed by district or divisional level officers.

The special Hill Area Development Programme has been implemented in 21 hill districts, of which eight were from Uttar Pradesh alone. The programme started with the basic objective of effectively utiilizing the indigenous resources of the hill areas and generating some employment through specially designed programmes for the utilization of the rugged land farms through the development of horticulture, plantation, agriculture, animal husbandry, poultry, beekeeping and forestay, in addition to the development of village industries. Soil conservation and rain-shadow area utilization were some of the other purposes of this programme. Special programmes too have been designed to replace the *jhum* form of cultivation to settled cultivation and also to rehabilitate the tribal people.

Tribal Area Development Programme

The Tribal Area Development Programme (TADP) was commenced in 1962. It aimed at an integrated development programme for the administrative unit areas with 50 per cent or more of tribal concentration. The programme was specially designed to suit the communities living in these areas and to incorporate special problem issues like the problems of shifting cultivation, land alienation, bonded labour, credit and marketing schemes, forestry and road transportation. By taking several socioeconomic and sociocultural issues like land tenure system and the scientific distribution of the different services in the areas various schemes were prepared.

Applied Nutrition Programme

The Applied Nutrition Programme was introduced way back in 1963, by the Government of India, through an agreement with international organizations like the FAO, WHO and UNICEF. However, the same has been taken up with the following objectives:

1. The short term objective of the programme was to wipe out the existing malnutrition from the rural areas, caused due to (a) calorie-protein deficiency, (b) iron deficiency, and (c) vitamin-A deficiency.
2. The long term objectives of the programme were: (a) to enhance the socioeconomic status of the rural population, and (b) to augment food production.

The UNICEF jointly with the government took a lead in launching this programme, particularly in the areas of acute malnutrition, with the supply of skimmed milk for infants, pre-school children, through child health care centres and other agencies working in the rural areas.

Intensive Agricultural Area Programme

In view of the encouraging results of the Intensive Agricultural District Programme (IADP) and the growing need of more foodgrains, the government decided to extend this programme to "areas where a high agricultural production potential exists" under the name of Intensive Agricultural Area Programme(IAAP). IAAP was launched in 1964-65 to ensure the intensive development of important crops like wheat, paddy, millets, pulses, cotton, etc., in 114 selected districts. The selection of districts for the IAAP was more or less based on the same criteria adopted in IADP.

The aim of IAAP was to bring about a progressive increase in the production of main crops in selected areas by intensive package approach. It was hoped that substantial increase in agricultural production could be brought within a short period through IAAP in certain favourable regions. It may be said that both the IADP and the IAAP are based on 'minimum effort' and 'big push' development theories. If higher level of productivity is achieved in selected areas, by using package approach of modern practices, it will have wider effects on the neighbouring areas also, leading to higher levels of productivity in different areas. The number of districts and blocks selected for IAAP was quite large, accounting for sizable cultivated area. The limited supplies of inputs had been an important limiting factor in the progress of IAAP. On the other hand, inadequacy of technical staff

adversely affected the implementation of the scheme. Both IADP and IAAP implemented within the limitations set for the then existing crop varieties which had relatively a low response to chemical fertilizers. However, both the IADP and IAAP successfully set the pace for introduction of HYV of seeds, leading to the Green Revolution.

High Yielding Varieties Programme

In 1965, a distinctive strategy was adopted to increase agricultural production with the massive use of modern inputs, i.e , irrigation facilities, chemical fertilizers, pesticides, new seeds, agricultural machinery and other equipments. As per the policy, the government announced the minimum price of foodgrains. The Food Corporation of India(FCI) prepared a plan to ensure that the farmers receive the minimum protection price by purchasing their surplus foodgrains at the price announced by the government. For massive use of modern inputs, financial assistance of loans were made available by the cooperative banks like land development banks and lately the commercial banks too came forward for the financial support and to ensure the implementation of the programmes.

Intensive Area Development Scheme

During 1965, the Intensive Area Development Scheme(IADS) was started by a team sponsored by the Ford Foundation. It recommended the selection of certain areas for more intensive efforts. District with irrigational facilities and assured rainfall were selected for IADP to boost their agricultural production. A district from every state was selected for intensive technical help, and to ensure the regular supply of chemical fertilizers, improved credit system and other supplies to the farmers through village panchayats and cooperatives. As a result of these measures, it was expected that the production of major crops would go up.

Three Annual Plans (1966-69)

The adverse economic situation in the country caused largely by severe droughts of 1966 and 1967 forced the government to declare a 'plan holiday' and in place of the regular five year plan, the country had three annual plans, i.e., 1966-67, 1967-68 and 1968-69. Also, the sixties witnessed the Green Revolution consequent to the introduc-

tion of new chemical fertilizers and high yielding seed varieties.

Table 10.5

Rural Development Programmes: Three Annual Plans

Programmes	*Year*
Farmer's Training and Education Programme	1966
Well Construction Programme	1966
Rural Work Programme	1967
Tribal Development Block	1968
Rural Manpower Programme	1969
Composite Programme for Women and Pre-school Children	1969
Agency for the Development of Marginal Farmers and Agricultural Labourers	1969

Source: The Annual Plans (1966-69), Government of India.

Fourth Five Year Plan (1969-74)

The Fourth Five Year Plan mentioned the crucial role of agriculture in view of the fact that 60 per cent of the total household consumption and 85 per cent of the commodity consumption comprised agricultural products or industrial products based on agricultural raw materials. Also price stability was a function of the growth of agricultural production The Fourth Plan envisaged a 5 per cent growth rate in order to eliminate dependence on imported foodgrains.

Further, the importance of agriculture had been mentioned in setting out the objectives, targets and strategy of the Fourth Plan in respect of agriculture. The pace of development in the agricultural sector set a limit to the growth of industry, of exports and of the economy, as a whole, and constituted a major condition for achieving economic and social stability and improving the standard of living and nutrition for the masses.

In the meeting of the working group on foodgrains production, it was stated that, while in the earlier five year plans, targets were directed largely by the needs of the country, based on projections of population, national income, etc., for the purpose of the Fourth Plan, the objectives should be slightly different and to be based on a realistic assessment of the production potential in respect of each of the major groups on foodgrain production decided to constitute study

teams on major crops, one each for rice, wheat, barley and maize, and one for millets and pulses. On the basis of reports of these study teams, the working group submitted its final report, which contained a review of the progress made in foodgrains production during the Third Plan period. The team also prepared an assessment, in the light of current trends and other available data and the position likely to be reached at the end of the Third Plan period and proposals for the Fourth Plan in the perspective of a ten-year period.

The Fourth Plan also mentioned shortfalls in pulses, animal products, oilseeds and cotton as the major problem areas. Another problem area was the fluctuation in output due to uncertainty of weather. In its review of previous plans, it mentioned that the eight years period between the commencement of the Third Plan and the Fourth Plan had been the period of great significance for Indian agriculture with the following important elements:

(i) The IADP, started in 1960-61 in three districts, and subsequently extended to another thirteen districts with its package plan approach and concentration of specific areas.
(ii) The introduction of HYV and hybridization techniques for wheat, maize and millets on a selective basis; HYV paddy seeds of exotic varieties introduced in 1965.
(iii) The role of agricultural technology as a major input for agricultural production.

Table 10.6

Rural Development Policy and Programme· Fourth Five Year Plan

Policy	*Programme*	*Year*
Special clientele based and area based programmes	Drought Prone Areas Programme	1970
	Crash Scheme for Rural Employment	1971
	Small Farmers Development Agency	1971
	Tribal Area Development Programme	1972
	Pilot Projects for Tribal Development	1972
	Pilot Intensive Rural Employment Projects	1972
	Employment Guarantee Scheme	1972

Source. The Fourth Five Year Plan, Government of India.

Drought Prone Areas Programme

A Rural Work Programme was started in 1970-71 in areas chronically affected by droughts with the principal objective of organizing permanent works to obviate scarcity relief and also to generate adequate employment through labour intensive schemes such as major irrigation works, soil conservation, afforestation and village and district roads necessary to open up the wider areas for agricultural production. After the mid-term appraisal during the Fourth Plan, this programme was redesigned as Drought Prone Area Programme(DPAP) and was reoriented as an integrated area development programme with the objective of developing the land, water, livestock and human resources of these areas. The programme had been in operation in 511 blocks of 70 districts in 13 states.

A task force was constituted in 1980 to review the ongoing special programme and development schemes taken up under DPAP to study the existing coverage of the DPAP; to lay down objective criteria for inclusion and exclusion of areas under the programme; to spell out the main components of the broad strategy of development under the programme and also to identify the linkage between DPAP and other ongoing rural development programmes.

Crash Scheme for Rural Employment

The Crash Scheme for Rural Employment was taken up for implementation during the last three years of the Fourth Five Year Plan. The scheme aimed at the making provision of employment of 1000 persons from each district through labour intensive works and creation of durable assets. The scheme was implemented throughout the country practically covering all the districts. During the three years the scheme generated employment equivalent to 316 million mandays.

But, a number of minor works were taken up without any preplanning. Roads formed the major chunk of the works executed during the plan, but most of them remained *kutcha* or semi-*kutcha* and there was no satisfactory arrangement for future maintenance of the roads. The scheme was operated uniformly in all the districts without taking into consideration the specific needs of any particular area.

Small Farmers Development Agency

The Small Farmers Development Agency(SFDA) scheme was approved to ensure the viability of the small farmers in the year 1970-71 but the actual implementation started from the year 1971-72.

During the Fourth Plan, the SFDA projects were started in 87 areas in the country. During the plan each project was expected to cover approximately 50000 families of identified small farmers owning a landholding ranging from 2.5 to 5 acres. Programmes based on land and animal husbandry were included in the project. Small farmers identified under SFDA programme were provided subsidy to the extent of 25 per cent capital investments and inputs. Besides, the loan facility from cooperative and commercial banks was also made available.

Up to 1978-79 the SFDA was a central sector scheme with 100 per cent assistance from the central government. But, from the year 1979-80, the scheme is being run as a central-state scheme and the financial burden is now shared on the 50: 50 per cent basis.

Tribal Area Development Programme

As already mentioned, the Tribal Area Development Programme was initiated in 1970-71. Under this programme, six pilot tribal development projects in Srikakulam district of Andhra Pradesh, Singhbhum district of Bihar, Dantewada and Konta tahsils of Bastar district in Madhya Pradesh, and Ganjam and Koraput districts of Orissa were sanctioned by the Government of India for the economic development of these areas. During the Fifth Plan two more projects were sanctioned for Keonjhar and Phulbani in Orissa. During the Fifth Plan, for the first time, a strategy of earmarking of funds for the development of scheduled tribe was evolved. Because of concentration of ST population in specific areas, the instruments of tribal sub-plan was developed to ensure the inflow of benefits from all sectors and to provide integrated delivery of services in the tribal areas.

The objectives were to minimize the gaps between the level of development among the tribal and non-tribal areas, and also to improve the quality of life of the tribal communities.

Pilot Intensive Rural Employment Project

It was started in November 1972 for a period of three years and then

extended over 15 blocks. The scheme has been considered as an experiment in full employment. It aimed to provide gainful employment on such work projects not requiring skills of a high order in selected compact areas for creating durable assets that will have continuing multiple effect of creating new jobs and will form part of the area development plan; to impart new skill for selected workers to find out continuous employment in the secondary and tertiary sector either in rural or urban areas: and finally, to phase the employment of the unemployed by one-third in every year so as to have full employment in the block within three years.

Later on it was not possible to provide the funds of the order envisaged, i.e., Rs. 450 per employee, due to financial constraints. In some cases all the person registered did not turn up. While, in other cases, the demand for work was ad hoc and works had to be adjusted according to availability of labour. In many cases there was inadequate planning and little in way of integration with the district plan programmes. There were administrative and organizational bottlenecks. Material component was also found to be inadequate to provide for durable assets.

Employment Guarantee Scheme

In 1972-73, the Maharashtra government initiated an Employment Guarantee Scheme to provide gainful employment in approved works practically to all unskilled persons in the state who needed work and were ready to do manual work in rural areas. Productive works of a labour intensive nature (60 per cent of cost as wages), leading to the creation of durable assets, were taken up. These programmes were to be executed by the available development personnel.

The aim of the Employment Guarantee Scheme was to provide gainful and productive employment not only to the individuals who are productive to the economy on approved works to all unskilled persons in the rural areas including the areas of 'C' class municipal councils who need work and are ready to do manual labour but are unable to find this on their own. The guarantee of work was restricted to unskilled manual work, persons selected under the scheme do not have a choice of work or the place of work. Though the guarantee is given at the district level, but operationally work is provided at the Panchayat Samiti level.

The fundamental objective of the scheme was that the works taken up should give proper results in the outcome in the form of durable community assets and the ways paid to the workers were linked with the quality of work to ensure better results and workers involvements.

Fifth Five Year Plan (1974-79)

The Fifth Five Year Plan described agriculture as the most vital sector. The approach of the Fifth Plan was based on studies of growth of output and the pattern it displayed which showed that in certain regions of the country, the growth in production of foodgrains was primarily explained by the spread of irrigation and multiple cropping, while in others, it was due to water, seed and fertilizer technology. In

Table 10.7

Rural Development Policy and Programmes: Fifth Five Year Plan

Policy	*Programmes*	*Year*
Introduces the concept of basic minimum needs	Command Area Development Programme	1974
	Minimum Needs Programme	1974
	Special Livesstock Production Programme	1975
	Twenty-Point Programme	1975
	Habitat Movement	1976
	Rural Functional Literacy Programme	1976
	Food for Work Programme	1977
	Desert Development Programme	1977
	Antyodaya	1977
	Comprehensive Area Development Programme	1978
	District Industries Centres	1978
	Operation Barga	1978
	Whole Village Development Programme	1979
	Integrated Rural Development Programme	1979
	Training of Rural Youth for Self-Employment	1979
	National Adult Education Programme	1979

Source: The Fifth Five Year Plan, Government of India.

the Fifth Plan, the strategy for long term planning in the agricu sector was about the exploitation of ground water and surface w intensification in application of new technology in the agricu sector, the extension mechanism, and programmes to regulate ensure the supply of inputs. The trend of diversification to com cial crops was expected to be maintained. Expansion of area u HYV of paddy was to be further intensified during the Fifth Plai riod. Various new programmes were added while the areas of th isting programmes were expanded during the Fifth Plan.

Command Area Development Programme

The Command Area Development Programme (CADP) was i duced in December 1974 by the central sector to include 47 irrig projects under 37 command area development authorities in 102 tricts of the 12 states. In addition to water conveyance and drai systems, the programme also lays emphasis on various develop activities for weaker sections of the community. The main foc this programme has been on the development of irrigation thr levelling and shaping, land construction of field channels, intro ing the '*warabandi*' system of water management, and finally popularization of integrated soil-crop water management practic

Minimum Needs Programme

The Minimum Needs Programme (MNP) was introduced in 1974 a continued in the following plans with additional financial allocat The programme was aimed at improving the quality of life and providing infrastructural facilities needed for supporting and su menting the other beneficiary programmes, helping the rural poo

The concept of this programme emerged and crystallized o experience of the previous five year plans that neither develop nor social consumption could be sustained unless they are integr and have mutually supportive activities. The programme lays d the urgency for providing social services according to nationally cepted norms within a time bound programme. The main co nents of the minimum needs programme include:

(i) elementary education,
(ii) rural health,

(iii) rural water supply,
(iv) rural roads,
(v) rural electrification, and
(vi) nutrition.

The integration of the MNP with other beneficiary programmes like IRDP, TRYSEM, etc., do have a more enduring impact on the problem of poverty in rural areas.

Special Livestock Production Programme

This programme was initiated in 1975-76 on the basis of recommendation of the National Commission on Agriculture. The main objectives of the programme were:

(i) to provide employment opportunities to the rural poor and also to supplement their income;
(ii) to increase the production of animal products like milk, wool, eggs, etc., through crossbreed heifer rearing and setting up sheep, poultry and piggery production units; and
(iii) to take up health, marketing and insurance cover schemes also.

Twenty-Point Programme

The Twenty-Point Programme was initiated in July 1975 by the then Prime Minister Mrs. Indira Gandhi with a view to ushering in a new era for the poor and the downtrodden, and was refurbished on January 15, 1982. The announcement of the New Twenty-Point Programme was, however, a logical extension of the Twenty-Point Programme announced in 1975. According to the Prime Minister, "the agenda for the nation has been dovetailed into the overall plan of development. It pinpoints the areas of special thrust which will show immediate tangible results for various segments".

The basic objectives of the programme include:

(1) to provide gainful employment in rural areas;
(2) to help the rural people to acquire the basic skills which would enable them to be gainfully employed in rural voca-

tions;

(3) to expose them for adopting a new technology to boost the production, both in agriculture and rural industries;

(4) to arrest the tendency on their part to migrate from rural areas to urban areas in search of employment and livelihood to continue to live in abject poverty as well as expose themselves to the hazards of the urban environment; and

(5) to help the rural families to emerge from poverty within a short period of time.

Habitat Movement

It would not be an exaggeration to say that in spite of our five year plans, the plight of the rural poor continued to worsen. Not that sincerity was lacking and genuine efforts were not made for the development of rural masses but the major shortcoming in the past was the lack of coordination among the concerned agencies. The rural problem is not confined merely to the lack of credit facilities or, for that matter, to the absence of infrastructural facilities. The problem has many facets and calls for concerted attention on several fronts if rural poverty is to be overcome.

Food for Work Programme

This programme was introduced in April 1977 as a non-plan scheme. As some surplus food stocks were available with the government, they planned to use it in this employment administration directly, without any help from labour contractors. One special advantage of the Food for Work Programme was its part wage payment in foodgrains at subsidized prices, which assured minimum nutrition to the beneficiaries. The Food for Work Programme was evaluated by the Programme Evaluation Organization of the Planning Commission. It pointed out that the major problems of the programme pertained to its administration and implementation. The Food for Work Programme continued up to 1980.

Desert Development Programme

Based on the recommendations of the National Commission on Agriculture, the Desert Development Programme was launched in 1977-78. The objective of the programme was to initiate the development

of desert areas with a view to provide more employment opportunities and to assure better income to the people residing in desert areas. This objective was sought to be achieved by:

(1) afforestation with special emphasis on shelter belt plantation, grassland development and sanddune stabilization;
(2) ground water development and utilization;
(3) construction or water harvesting structures;
(4) rural electrification for energizing pumpsets and tubewells; and
(5) development of agriculture, horticulture and animal husbandry.s

Antyodaya

There were many schemes to help the weaker sections in our country. The schemes were either sponsored by the central government or were initiated by the state governments. The basic objective common to all the schemes was to bring about improvement in the income position of the weaker sections. Every scheme was based on some approach or concept. An attempt was made here to discuss critically the approach or concept at 'antyodaya'. The scheme was included in the budget of the Rajasthan government in the year 1977. It would have been too early to pass any verdict on the efficacy of the scheme to improve the economic condition of the poorest in the villages. Instead of undertaking and exercise of this type, it became desirable to critically analyze the concept of 'antyodaya'.

Comprehensive Area Development Programme

The West Bengal Comprehensive Area Development Act of 1974 was meant to provide for the development of the state of West Bengal through area based development programme with a view to increasing agricultural and allied production and ensuring maximum benefits of such production to the cultivatiors. Agricultural production includes production of agriculture, horticulture, pisciculture, forestry, sericulture, beekeeping, dairy farming, piggery and poultry farming and also includes such other types of production as are ancillary or incidental thereof.

The guiding principle of the comprehensive area development

was formulated by the State Planning Board to take up the overhousing of the existing inequitable and anti-productive socioeconomic structure which was an essential condition for the full utilization of the technologically possible maximum rate of growth of production.

District Industries Centres

The experiment of the District Industries Centres has not proved to be very satisfactory. The statement on industrial policy recently issued by the Government of India has referred to the need for evolving a suitable alternative to the District Industries Centres. The matter is pending for consideration with the Ministry of Industry. At this stage, it is difficult to anticipate the form of the new set up. However, it has been recommended that the District Industries Centre or its alternative should fully and actively be involved in the programmes of the khadi and village industry sector. As far as possible, these programmes may be implemented under the industrial development as it may emerge at district and subdistrict levels.

Whole Village Development Programme

Recognizing the urgency of increasing productive capability in rural areas and promoting the welfare and prosperity of the people by an equitable distribution of the benefits of development, the National Commission on Agriculture recommended the adoption of a whole village approach for development with a view for harnessing the growth potential of the villages which were covered. The central theme of the whole village approach was to build the programme of development around the community as a whole. The programme components of the whole village development approach consisted of the following: (1) consolidation of holdings; (2) overall land development plan for maximizing water control and moisture preservation in dry areas; (3) maximizing irrigation support subject to per acre maximum limit of investment based on the need to repay investment credit by extra production; and (4) cropping programme for the village for the best use of irrigation and for ensuring the best control of irrigation and drainage.

Integrated Rural Development Programme

To ameliorate the condition of these underprivileged people, many

schemes, such as Community Development Projects, Small Farmers Development Agency, Marginal Farmers Development and Agricultural Labour, Drought Prone Area Development were started by the government. However, it was realized that despite all these programmes, the majority of the rural population continued to remain in the grip of grinding poverty. Thus, with a view to improve the economic and social life of the poorest of the poor living in the rural areas, a new development strategy was designed as Integrated Rural Development Programme(IRDP). Though the idea was conceived in March 1976, the IRDP could be launched in 1978-79 in 2300 blocks and was extended to cover all the 5011 blocks of the country with effect from October 1980.

The main objective of the IRDP is to improve the economic and social condition of the poorest section of rural society. It aims at raising their levels of living and bringing them above the poverty line on a lasting basis by giving them income generating assets, credit facilities and other inputs.

The families eligible for assistance under this programme are those whose annual family income is less than Rs. 4800 per year. It also includes cultivating families whose size of operational holding is less than five acres. Amongst these families the poorest ones are provided assistance. Special attention is being paid towards rural women under the IRDP. There is a special component of the IRDP for organizing rural women for productive activities on a group basis. The identified poor rural women are provided training and with suitable assets for increasing their family incomes.

The IRDP is a centrally sponsored scheme funded by the centre and the states on 50 per cent basis.

Training of Rural Youth for Self-Employment

A national scheme for Training of Rural Youth for Self-Employment (TRYSEM) was launched by the central government in August 1979. The aim of the scheme is to equip the rural youths with necessary skills and technical knowledge with a view for enabling them to seek self-employment.

It was one of the objectives of this programme to impart training and education in different trades, viz., blacksmithy, carpentry, poul-

try, shoe-making, cloth dyeing, printing and tailoring, etc. Under this scheme, persons in the age group of 18-35 years, and belonging to the target poverty groups of small and marginal farmers, agricultural labourers, rural artisans and others below the poverty line, are considered eligible for training. TRYSEM as a part of IRDP, aims at training for two lakh rural youths every year at an average rate of 40 youths per block. Besides imparting training, the scheme envisages organizational and operational linkage with other institutions, so that credit, marketing, supply of raw materials, etc., may also be provided to the trainees at the appropriate time.

Under the scheme trainees are paid Rs. 130 per month as stipend for six months. Besides this, training centres are to get Rs. 50 per month per trainee towards training expenditure.

As per the provisions of the scheme at least 30 per cent of the trained youths should be from SCs and STs and 33.5 per cent of the total rural youths trained should be reserved for women.

National Adult Education Programme

The National Adult Education Programme (NAEP) was launched in 1978-79 and gradually, it was extended throughout the country. The objective of the programme is to educate adults in the age group of 15-35 years so as to: (1) enable them to pursue a course of literacy instruction; (2) to make them critically aware of the environment around them; and (3) to give them opportunities to raise their functional competence to their changing environment.

The programme is very important and deals with the most fundamental aspect of development, that is, literacy.

Sixth Five Year Plan (1980-85)

The Sixth Five Year Plan aimed at an annual average increase of 3.9 per cent in the gross value added in agriculture, and 5 per cent in agriculture production, as compared to the past trend of a little less than 3 per cent in gross value added. The agricultural development was considered crucial for attaining 5.2 per cent growth in gross domestic product (GDP). Similarly, the success in the export efforts also depends on augmenting the agricultural production. Therefore, agriculture was given a high priority in all policies and programmes.

Four Es were mentioned in the Sixth Plan in reference to the objectives:

(a) *Ecology*. integrating ecological considerations in land use patterns, dealing with problems of waterlogging, salination and erosion; and contingent plans for different seasons.
(b) *Economics*: dealing with the entire production-trade-consumption chain.
(c) *Energy*: optimum use of non-renewable resources
(d) *Employment*: meaningful employment through subsidiary occupations

Table 10.8

Rural Development Policy and Programmes Sixth Five Year Plan

Policy	*Programmes*	*Year*
Emphasis on strengthening the socioeconomic infrastructure in rural areas, eliminating rural poverty, and reducing regional disparities through IRDP	National Rural Employment Programme	1980
	Prime Minister's New 20-Point Programme	1980
	Biogas Programme	1981
	Development of Women and Children in Rural Areas	1983
	Rural Landless Employment Guarantee Programme	1983
	Self-Employment to Educated Unemployed Youth Programme	1983
	Special Programmes for Women and Children	-
	Programme for Depressed Areas	-
	Village & Small Industries	-
	Dairy Development Programme	-
	Tribal Development Agency	-
	National Seeds Programme	-
	Intensive Pulses Development Programme	-
	Summer Moong Production Programme	-
	Intensive Cotton Development Programme	-
	Khadi and Village Industries Programme	

Source The Sixth Five Year Plan, Government of India

The major thrust of the Sixth Plan was to eliminate poverty and reduce regional disparities. The concept of integrated rural development was first introduced in 1976-77. It was further expanded to cover 2300 blocks in 1978-79. By March 1980, 2600 blocks were covered under this programme. The programmes such as Small Farmers Development Agency, Drought Prone Areas Programme and Desert Development Programme, under which only a small fraction of the rural poor were covered in the past and were included in the Integrated Rural Development Programme. As a result, the programmes for the rural poor operating through a multiplicity of agencies were ended and replaced by a single integrated programme. The operational strategy of IRDP comprised 57 development profiles, based on scientific understanding of the potential. It included agricultural extension to marginal farmers, linkages of the secondary and tertiary sectors, a credit plan for target groups, and preparation of block and district plans.

National Rural Employment Programme

The National Rural Employment Programme(NREP) owes its origin to the earlier Food for Work Programme which was started during the Fifth Plan as a non-plan scheme to augment the resources of the state government for the maintenance of public works on which large investments had been made. Based on the experience gained in the implementation of the Food for Work Programme for three years and also taking into account the constraints pointed out by the Programme Evaluation Organization of the Planning Commission, the programme was revamped, restructured and renamed as National Rural Employment Programme from October 1980. Up to March 1981 it was fully financed by the central government. However, from April 1981, it became an integral part of the Sixth Plan and is being implemented as centrally sponsored scheme on 50: 50 sharing basis between the centre and the states.

The programme has three objectives: (i) to generate additional gainful employment to the extent of 300-400 million mandays per year during the Sixth Plan for the unemployed and underemployed from the rural areas; (ii) to create durable community assets for strengthening rural infrastructure ; and (iii) to improve the nutritional standard of the rural poor. The progress achieved during the Sixth

Plan shows that its employment targets were fully achieved.

Biogas Programme

The Biogas Movement was launched in 1981 jointly by the Government of India and Khadi & Village Industries Commission as an alternative source of energy and for more effective utilization of animal and human wastes. Its importance in improving the standard of living of people has also been considered. However, the lack of any empirical and scientific studies in this area motivated the researchers to undertake various research works with the following specific objectives: (1) to compare the time utilization pattern of biogas owning and non-biogas owning families in food preparation activities; (2) to study their daily time utilization pattern in farm and home activities; and (3) to estimate the saving in labour by the biogas owning families.

Development of Women and Children in Rural Areas

This programme was launched as a subscheme of Integrated Rural Development Programme and is being implemented on a pilot basis in 50 selected districts spreading in 22 states in the country. The thrust of the programme has been to cover the women from the families below the poverty line residing in rural areas by organizing them into groups and enabling them to take up activities which would help them to increase their income and make them aware of problems they face and services they are to make use of.

Rural Landless Employment Guarantee Programme

Several programmes and schemes to provide employment and to eliminate poverty were taken up in the rural areas. Accordingly, a new programme called the Rural Landless Employment Guarantee Programme was formulated and launched in August 1983. The basic objectives of the programme include: (1) to improve and expand employment opportunities to rural landless with a view to provide employment for at least one member of every landless labour household up to 100 days in year; and (2) for creating durable assets for strengthening the rural economy. Among the landless persons those belonging to the scheduled castes/scheduled tribes are to be given priority.

Special Programmes for Women and Children

Special programmes for women and children had been introduced by the Central Social Welfare Board and the Mahila Mandals. During the Fourth Plan, social welfare activities included the provision of integrated services to children from the villages, specially to pre-school children, and the provision of basic training to women in home craft, mother craft, health, education and childcare. During the Fifth Plan, child welfare was accorded the highest priority in the social welfare sector. To ensure the healthy growth and development of children, specially those in the age group of 0-6 years, a scheme of integrated childcare service, with emphasis on supplementary nutrition immunization, health check up and nutrition education, was launched on a fairly wide scale. The scheme was to cover pregnant and nursing mothers, particularly those belonging to the weaker sections of society, with a view to check the infant and maternal mortality rates. A programme of functional literarcy, which would endow women with the necessary knowledge and skills to perform such functions of a housewife as childcare, nutrition, healthcare, home economics, etc., has been very useful for women in the age group of 15-45 years.

Programmes for Depressed Areas

The development of the depressed areas was mainly the responsibility of the states, but central government actively participated in it by: (1) providing the technical support of planning as well as programme development; (2) by channelizing institutional resources on a priority basis; (3) by continuing and further extending the liberal patterns of its assistance; and (4) by providing special incentives for the flow of private into identified backward areas.

Village & Small Industries

Village and small industries have made a significant contribution towards employment in the rural areas. In view of the objectives of expended employments large production and more equitable distribution, the task to be accomplished became cumbersome. The objectives of the programme have been clearly set out by the government in the Industrial Policy Resolution of 1977. The main thrust of the new policy was on the effective promotion of cottage and small scale industries widely dispersed in rural areas and small towns. It has

been laid down that whatever can be produced by the small and cottage sector must only be so produced.

Dairy Development Programme

Dairy development occupies a crucial place in the scheme of agricultural and rural development in view of its immense potential to benefit the rural poor, specially small and marginal farmers and landless agricultural labourers. Dairying has the potentiality of providing full-time employment for some and part-time employment for many. At present, there seems to be no clearcut policy with regard to the development of dairying alongwith crop production.

The success achieved in Operation Flood I and II in Gujarat must be made known to the rural people in the other parts of the country and there must be necessary help and encouragement to the rural poor in this regard. The emphasis under the National Dairy Development Project should be on organization of village level cooperatives and district level cooperative unions of milk producers and organization to supply the necessary inputs and processing and marketing facilities.

Seventh Five Year Plan (1985-90)

The central thrust of the Seventh Five Year Plan was to accelerate the growth of rural areas. Rural development means an attack on rural poverty. An amount of Rs. 52000 crores was earmarked in the Seventh Plan for the development of the rural areas. It accounted for nearly 65 per cent of the total plan outlay, excluding the outlay on industry, energy and transport, which accounted for more than Rs. 100253 crores.

The central element in the development strategy of the Seventh Plan was the generation of productive employment. This has been achieved by an increase in cropping intensity, made possible by increased availability of irrigation facilities, extension of new agricultural technology, specially to low productivity regions and to small farmers; through measures to make the rural development programmes more effective in the creation of productive assets; through the expansion of labour intensive construction activities to provide housing, urban amenities, roads and rural infrastructure; through the expansion of primary education and basic health facilities; and

through changes in the pattern of industrial growth.

The objectives and thrusts of the Seventh Plan have, therefore, been formulated as part of the long term strategy to be achieved by the year 2000 AD to virtually eliminate poverty and illiteracy, and to achieve almost full employment to secure the satisfaction of the basic needs, i.e., food, clothing and shelter and to provide health services to everyone. The plan thus sought to assist in the establishment of an economy and policy which is modern, efficient, progressive, humane, and encourages equity and social justice.

Table 10.9

Rural Development Policy and Programmes: Seventh Five Year Plan

Policy	*Programmes*	*Year*
NA	Community Development	NA
	Integrated Rural Development Programme	NA
	Rural Landless Employment Guarantee Programme	NA
	Drought Prone Area Programme	NA
	Integrated Rural Energy Planning Programme	NA
	Desert Development Programme	NA
	Border Areas Development Programme	NA
	Command Area Development	NA
	Biogas Development	NA
	Social Welfare Strategy	NA
	Jawahar Rozgar Yojana	NA

Source: The Seventh Five Year Plan, Government of India

Community Development Programme

For the purpose of the Seventh Plan, community development and panchayati raj would have to be viewed in this context and would have to break free from conventional methodology of including a large number of small schemes with minimal budget provisions. What goes by the name of community development in the documents would have to be viewed now more in the nature of a scheme for village development, which would imply the planning and implementation of a number of residual activities at the village level which do not get covered in the normal sectoral plans and special programmes,

e.g., village paths, drainage and sanitation.

Integrated Rural Development Programme

Many of the shortcomings of the Integrated Rural Development Programme(IRDP), with massive dimension, was launched with what may be called very little preparation. The Sixth Plan period may thus be called a period of trial in which the programme gradually came to be known, understood and even stabilized. The gaps that have been revealed and the weaknesses that have been experienced in the process to be removed during the Seventh Plan so as to make the IRDP an effective instrument of poverty alleviation. The programme will continue to aim at the poorest among the poor who will be identified by an annual income of Rs. 4800 which is substantially lower than the cut off point income of Rs. 6400 at the poverty line level. Towards achieving this end, much greater has to be exercised in the process to select the beneficiaries.

The Special Livestock Production Programme, which had continued in the Sixth Plan as separate programme, although financed through IRDP outlays, will be merged with the IRDP under which substantial activity in the milch cattle sector had in any case been noticed. The pattern of assistance under the Special Livestock Production Programme will, wherever feasible, be provided under the main IRDP. With the merger of this programme with the IRDP, and considering the normal emphasis on milch cattle that is likely to continue in the IRDP, even otherwise, there is likely to be a substantial demand for good quality heifers and other milch animals. Keeping this in view, a new breeding programme, i.e., Special Livestock Breeding Programme, has replaced the Special Livestock Production Programme during the Seventh Plan.

Drought Prone Area Programme

The strategy adopted in the Sixth Plan for DPAP was continued during the Seventh Plan which would inter alia include increased stress on activities contributing directly to the restoration of the ecological balance and increasing the per capita income through the effective development of land and other natural resources, including an efficient utilization of scarce water, conservation of scanty rainfall, and arrest of its runoff in drought prone areas. For DPAP, the existing

pattern of assistance and the funding norm per block per year would be continued during the Seventh Plan, in which an outlay of Rs. 237 crores as central share has been provided.

Integrated Rural Energy Planning Programme

On the basis of experience of the pilot IREP during the Sixth Plan in the selected states, the programme would be fully activated in all the stated and union territories during the Seventh Plan. Efforts would also be made to develop the institutional mechanism in all the states/union territories for the planning and implementation of the integrated projects in selected blocks from each state.

The IREP in the Seventh Plan would consist of the following components:

(1) development of institutional mechanism in the states/union territories;
(2) training;
(3) projects preparation;
(4) projects implementation;
(5) provision of financial incentives; and
(6) monitoring.

These components would be funded from central and state financial outlays for IREP. The central financial component would be utilized to set up an institutional mechanism for staff support and their training, and the monitoring programme. The state financial component would be utilized for project preparation; project implementation, which would include demonstration and extension programme; grants of local institutions and industries; and for the provision of financial incentives to users and manufacturers for IREP projects.

Desert Development Programme

The subgroup on Area Development and Land Reform of the Seventh Plan Working Group on Rural Development has recommended a higher allocation of funds for the hot arid areas. It has recommended that the existing rate of Rs. 10 lakhs should be raised to Rs. 15 lakhs per 1000 sq kms to start with, and gradually to Rs. 25 lakhs

per 1000 sq kms in the terminal year of the Seventh Plan (1980-90), with corresponding ceilings of Rs. 4 crores per district per annum to begin with and Rs. 6 crores in the last year.

For the cold arid areas, a total allocation of Rs. 25 crores has been recommended during the Seventh Plan. The scale of funding for the cold arid areas from 1985-86 was Rs. 75 to Rs. 175 lakhs per annum per district, as against Rs. 50 lakhs in the earlier plan. The enhancement of allocation has been made to step up the development in the hot arid areas.

In the Seventh Plan, the entire amount for the Desert Development Programme would be provided to states by modifying and covering the existing 50 per cent matching centrally sponsored scheme into a 100 per cent central scheme.

Border Areas Development Programme

A new programme for the development of border areas has been proposed to be taken up in the Seventh Plan. An amount of Rs. 200 crores has been allocated as part of the Special Areas Development Programme for this purpose. The development of border areas has taken an increasing importance due to developments in the recent past. Attention has been made for the balanced development on sensitive border areas. It has been decided to initiate a programme for the development of such border areas as a 100 per cent centrally funded programme to be administered by the Ministry of Home Affairs.

Command Area Development

The main emphasis during the Seventh Plan would be on ensuring, through suitable measures, an effective coordination of the concerned activities of these departments under one authority. The Command Area Development Authority would ensure the availability of the basic agricultural inputs by advance planning. Close monitoring and evaluation had been the main thrust of the CAD programme during the Seventh Plan.

In the Sixth Plan, the central assistance was distributed on the basis of a matching provision made in the state plans. No specific weight was given to the states which were economically backward and could not provide the matching provision for the CAD pro-

grammes. In the Seventh Plan central assistance had been distributed to the states in such a manner so that economically backward states would be given a higher share of the central sector outlay, consistent with the CAD programme undertake in the states.

Biogas Development Scheme

Biogas is cheap and efficient fuel and its feedstock is a renewable source of energy. The manure produced from biogas plants is better, both quantitatively and qualitatively than ordinary farmyard manure. The social benefits of biogas include:

(1) reducing the indiscriminate felling of trees for fuel and consequent deforestation;
(2) reducing the incidence of eye diseases among village women and children;
(3) improvement in rural sanitation: and
(4) easy cooking, elimination of the drudgery of rural women's life and leisure for development activities.

The scheme is being continued during the Seventh Plan period. A target of 5.5 lakh family based biogas plants has been fixed for the Seventh Plan period, with a plan outlay of Rs. 177 crores. Presently, the project provides for technical design and support, training programmes, service facilities, repair, and maintenance, monitoring and evaluation, central subsidy, turn key job fee, etc.

Social Welfare Strategy

The social welfare programmes are designed to supplement the larger effort at human resource development. The objective is to improve the quality of life and the handicapped through organized and sustained development activities. Social welfare services are, therefore, preventive, primitive, developmental and rehabilitative in nature.

The welfare of children women and the disable is linked with the development of the family—the basic social unit. Child welfare would be given the highest priority. The basic minimum childcare services would be extended to the most vulnerable group of 0-6 years

of age in order to reduce the high incidence of child mortality, morbidity and malnutrition in the country. Greater emphasis will be laid on enhancing the capabilities of the mother to look after the health and nutritional needs of the children. Stress would be laid on further strengthening the supportive services to the family.

Jawahar Rozgar Yojana

The critical problems of Indian economy, viz., poverty and unemployment, prevalent particularly in rural areas of the country, needed some effective solution on a sustained basis. As such, a progressive scheme, called Jawahar Rozgar Yojana(JRY), was introduced in April 1989, which is now being implemented all over the country.

The existing schemes, known as National Rural Employment Programme and Rural Landless Employment Guarantee Programme, have been merged into JRY which is to provide employment to at least one member of each poor family for 50 to 100 days in a year in the vicinity of places of their residence. Of the total expenditure incurred, 15 per cent have to be provided to the SCs and STs, while the beneficiaries under the JRY, 30 per cent to be given to the women.

JRY was launched with the following main objectives:

(1) to generate additional gainful employment for the unemployed and underemployed persons, both men and women from the rural areas; and

(2) to create the productive community assets for direct and continuing benefits to the poverty groups and for strengthening rural, economic and social infrastructure that will lead to rapid growth of the rural economy along with a steady rise in the income levels of the rural poor.

The Jawahar Rozgar Yojana has, however, not been properly implemented and the needy, poor and unemployed have not been benefited at the desired level.

Eighth Five Year Plan (1995-1999)

The strategy and thrust of the Eighth Five Year Plan is to consolidate the gains from the base built over the years in agricultural production, sustaining the improvements in productivity and production to meet the increasing demands of the growing population, enlarging

the incomes of farmers, and realizing the country's potential by stepping up agricultural exports. While the production of several commodities has shown significant increases, a cause of major continuing concern is that the growth rates in agricultural production are highly skewed in terms of different regions and crops. Rapid improvement in productivity and production of a few of agricultural crops, since the introduction of HYV from the mid-sixties, has been conspicuous only in small pockets of well endowed irrigated areas. Eastern India lying in the heavy rainfall zone, the vast rainfed arid tracts in the country and the hill regions have not been able to adopt the technologies for achieving high growth rates. It will be of crucial significance, not only on account of the need to reduce regional disparities, but also essentially to raise production levels, that far greater attention in devoted to bring about an accelerated growth in areas which have relatively lower growth.

It was with this objective that in the rainfed areas, farming system approach should be the basis for enabling farmers to make sufficient and optimum use of their lands and water resources to increase their incomes. Diversification of agricultural production systems may be called for, together with scientific management of land, to prevent soil erosion and achieve better *in situ* moisture conservation.

Since a preponderant proportion of landholding is small or marginal, the income of these farmers even in the best productivity areas may not be sufficient. Emphasis, therefore, was laid on the diversification into other allied activities, capable of generating higher returns. Such allied activities include animal husbandry, horticulture, sericulture, fisheries, agroforestry, etc.

For the generation of rural employment in the areas of poor growth of agriculture, the treatment of rainfed areas on watershed basis may provide employment opportunities for unskilled labour by way of construction of water harvesting structures, plantation of horticulture, and agroforestry. Even in the irrigated areas, employment could be generated by increasing productivity through dissemination of improved technologies. Watershed management principles were emphasized in this plan for environmental concerns in the ecologically fragile areas like the undulating rainfed lands and the hilly terrains. The efficient use of chemical fertilizers, recycling of organic

wastes, use of plant protection chemicals and biofertilizers have an important place in the sustainable agricultural development process Moreover, the marketing infrastructure has to be further augmented and streamlined, especially in respect of perishable commodities (vegatables , milk, meat and fruits) Expansion of agrobased industries was also suggested to creat more jobs for the rural youths

Many of the programmes and schemes have to be continued from the Sixth Plan, with necessary refinements/modifications to address themselves sharply to the problems they seek to overcome In order to achieve this objective, emphasis was given on the land reform measures through provision of security to tenants, consolidation of landholdings and ceiling of surplus land A suitable price policy was also designed to ensure adequate return on investment made by the farmers

The targets of crop production as well as likely area to be devoted to principal crops were fixed and have been given below in Table 10.10.

Table 10.10

India—Changing Patterns of Area, Production and Yield—1991-92 and 1996-97

	*1991-92**			*1996 97*		
	A	*P*	*Y*	*A*	*P*	*Y*
Rice	42 50	72 50	1706	43 50	88 00	2023
Wheat	23 50	56 00	2383	24 25	66 00	2722
Coarse Grains	37 50	30 00	800	37 75	39 00	1033
Pulses	23 50	14 00	596	24 50	17 00	694
All Foodgrains	127 00	172 50	135	130 00	210 00	1615
Oilseeds	23 50	17 50	74	24 50	23 00	939
Sugarcane	3 70	235 00	63514	3 90	275 00	70513
Cotton**	7 40	10 50	241	7 50	14 00	317
Jute & Mesta***	1 00	9 00	1620	1 00	9 50	1710
Other Crops	19 60			23 70		
All Crops	182 20			190 60		

A-Area-million hectares
P-Production-million tonnes
Y-Yield kg/ha
* Likely achievements
** In million bales of 170 kg each
*** In million bales of 180 kg each

Crop Production Oriented Programmes

The crop production oriented programmes in the Eight Plan include the special Food Production Programme for rice, wheat, coarse cereals, oilseeds, pulses, cotton, etc. Adequate emphasis was also laid on horticulture crops (floriculture, fruits, vegetables, cutflowers, etc).

The other programmes undertaken during this plan include: (i) Animal Husbandry and Dairy Development, (ii) Agricultural Research and Education for which Krishi Vigyan Kendras (KVK) or Farm Science Centres were proposed to be established in different districts in the country.

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11 Green Revolution in India

'Green Revolution' is a term coined to describe the emergence and diffusion of new seeds of cereals. The new cereals were the product of research work and concentrated plant breeding with the objective of creating High Yielding Varieties (HYV) of use to the developing countries. New varieties of wheat were first bred in Mexico in the 1950s and new varieties of rice, like IR-8 (miracle rice), at the International Rice Research Institute, Philippines in the 1960s. The increase in yield from the new seeds has been spectacular. In some cases, the yield of HYV is more than double the yield of traditional varieties.

The Green Revolution has been used to mean two different things. Some experts of agricultural geography use it for referring to a broad transformation of agricultural sector in the developing countries to reduce food shortages. Others use it when referring to the specific plant improvements, notably the development of HYV. Whatsoever the meaning of Green Revolution may be taken, the adoption of HYV of wheat and rice has been considered as a significant achievement as it offered great optimism, In fact, these varieties of seeds have revolutionized the agricultural landscape of the developing countries, and thereby the problems of poverty, hunger and undernourishment have been reduced in certain regions of the developing countries.

In India, the hybridization of selected crops, i.e., maize, *bajra*

(bulrush millet) and millets began in 1960. The Maxican dwarf varieties of wheat were tried out on a selected scale in 1963-64. Exotic varieties of paddy such as Taichung Native I were introduced in India in 1966. The diffusion of HYV, however, became fully operational in the country in the *kharif* season of 1965-66 in which about 17000 hectares of cultivated land was brought under HYV, especially in the Sutlej-Ganga plain and the Kaveri delta. The IR-5 was developed in 1967 and IR-22 in 1969, while the IR-24 was released in 1971. Subsequently, a number of new varieties of rice and wheat have been developed by the Indian agricultural scientists and adopted by the farmers of the country.

Merits of High Yielding Varieties

HYV have certain advantages over the traditional varieties of cereals which may be summarized as under:

1. HYV have shorter lifecycle and thereby enable the farmers to go for multiple cropping. For example, new seeds of rice and wheat complete their lifecycles in 110 and 120 days respectively. The traditional varieties of rice and wheat, on the other hand, take about 130 and 150 days respectively to harvest. The new seeds thus enable the farmers to economize on land.
2. HYV need a lot of water for better yields. The yield per unit area is significantly high. If it is considered in terms of water required per quintal of wheat or rice, the new seeds require less water as compared to that of the traditional varieties. HYV thus economize on water also as the crop remain in the field for a shorter period.
3. HYV under optimal conditions require more labour per unit area, and thus help in generating more employment. Prior to the introduction of HYV, the farmers over greater parts of the country, especially in the rainfed areas, were exclusively dependent on the arrival of monsoon for the commencement of their agricultural activities. They used to remain unemployed during the months of summer season (May and June) after the harvest of *rabi* crop. But now, the farmers and the dependent labourers get work in various agricultural operations through-

out the year.

4. HYV are scale neutral which means that other things being remaining the same, the big farmers and the small farmers are likely to get the production and profit in the same proportion. In other words, the new seeds are not bised towards the big or the small farmers.
5. The adoption of HYV does not require any special skill and farmers of various socioeconomic and cultural backgrounds can adopt the new seeds easily. A minor adjustment in the dates of wheat is required as HYV need relatively cool temperatures at the time of sowing. For example, in Punjab and Haryana, the sowing dates of wheat prior to the Green Revolution were in the third or last week of October when the day temperature used to be around 35°C, but now wheat is generally sown in the Sutlej-Ganga plain not before the middle of November when the day temperature reads about 30°C and the night temperature falls around 18°C. The farmers have, however, very well adjusted their sowing and harvesting dates on the basis of their experience during the last thirty years.

When the package programme and new agricultural strategy were adopted in the mid-sixties, it was expected that the problems of food shortage, poverty, hunger, malnutrition, undernourishment and economic inequalities will be largely solved, but these objectives could not be fully achieved because of certain geoecological and socioeconomic constraints in the cultivation of HYV. The geographical conditions required for the successful cultivation of HYV have been discussed hereunder.

Socioeconomic Constraints in the Adoption of High Yielding Varieties

HYV are undoubtedly land substituting, water economizing, more labour using, and employment generating innovation; nevertheless, they are very delicate and sensitive and therefore require a great deal of care if a successful harvest is to be obtained. For example,the new seeds are less resistant to droughts and floods and need an efficient management of water, chemical fertilizers, insecticides and pesti-

cides. Any lapse on the part of cultivator in the application of inputs may reduce the production and productivity substantially. In order to get a satisfactory agricultural return,the farmer should be in a position to arrange the costly inputs on time for which sufficient surplus capital should be available. In the case of non-availability of capital, the farmer should have an easy access to the credit facilities. A brief discussion on the inputs and infrastructure requirements for HYV is imperative to ascertain the myth and reality of the success of the Green Revolution in India.

Irrigation

Irrigation is the most important input required for the successful cultivation of HYV. Adoption of new needs and intensification of agriculture in the subtropical countries like India (characterized with erratic monsoon) are not possible unless adequate irrigation facilities are available. Better results from HYV depend largely on assured and controlled irrigation. The new seeds require water at specific periods of growth, development and flowering. The timings of irrigation and the quantity of water supplied are decisive for the performance of the crop. The associated inputs like chemical fertilizers, insecticides and pesticides also perform satisfactorily only if timely irrigation is provided to the crop. It may be emphasized that excessive irrigation and inadequate irrigation are both injurious to HYV of wheat and rice. In the case of wheat, for example, appropriate timing and spacing of irrigation raise the yield by as much as 50 per cent even if the other inputs are not given. The first irrigation to wheat around the third week of sowing alone raises yield by as much as 30 per cent than that when it is delayed. These varieties require irrigation after every three weeks during the period of growth and development and after every two weeks at the flowering and primordial stages. In the case of rice, inadequacy of moisture in the primordial initiation (flowering, milking and grain forming stages) can reduce production to the extent of 50 per cent. To meet water requirements, there must be a controlled source of water at the disposal of farmers. Apart from canals, the government tubewells, pumping sets and tubewells installed by the farmers are necessary to fulfil the water demand of the new seeds. The farmers of Punjab and that of the upper Ganga-Yamuna doab (Meerut division) are unanimous in their opinion that HYV of wheat

and rice give double the yields per unit area, provided timely irrigation is made The other inputs like chemical fertilizers and plant protection chemicals can enhance the yield further Without irrigation, a surfeit of other inputs, therefore, be of no avail

In the areas exclusively dependent on rains (Brahmaputra valley) and in the dry farming areas (Rajasthan, Marathwada, etc) soil moisture requirements during the various stages of growth of crop cannot be controlled Consequently, the HYV in such areas either could not be diffused or they are not performing satisfactorily In fact, in the absence of controlled irrigation chemical fertilizers cannot be applied with confidence and many a times their application affects the crop adversely, particularly if the soil is not sufficiently moist Irrigation is thus the single most important input on which depends the success or failure of a crop

HYV are, however, not very successful in the areas of heavy rainfall For example, in the valley of Brahmaputra, Barak, and the hilly tracts of northeast India, there is heavy rainfall during the summer season Excessive rainfall, immediately after the application of chemical fertilizers or that of plant protection chemicals, reduces their utility and effectiveness These costly inputs may go as a waste after the floods resulting from heavy rains One of the important factors which contributed to the success of new seeds in the states of Punjab, Haryana and western Uttar Pradesh is the elaborate irrigation infrastructure in the form of canals, tubewell and pumping sets In several districts of Punjab and Haryana irrigation facilities are available to each and every hectare of land Even in the years of droughts (1987-88 and 1988-89), the farmers could harvest very good crops of paddy with the help of canal and tubewell irrigation HYV are water thirsty They require several watering at the critical stages of growth and flowering In the absence of irrigation facilities, the farmers may not get even reasonable returns from their field Thus controlled irrigation is the key to success of new varieties of cereals

Availability of Chemical Fertilizers

The natural fertility of land is declining with the passage of time In a region like the Indo-Gangetic plain where agriculture is being practised for over the last 8000 years the soils are depleted and are increasingly losing their resilient characteristics For the recuperation

of fertility, the soils are rested in the form of fallowing or they are enriched by applying manures (compost and green) and chemical fertilizers (NPK).

HYV give rise to short stemmed, stiff strawed plants that respond well to heavy dozes of fertilizers. These dwarf varieties give much higher yields per unit area. The response of traditional varieties to chemical fertilizers is more in terms of vigorous vegetative growth which leads to preharvest lodging of the crop. The lodging of crop reduces the yield per unit area.

After irrigation, chemical fertilizer is the second most important input required for the successful cultivation of HYV. The recommended dose of chemical fertilizer for the new seeds of wheat and rice in terms of NPK in 90-45-45 kg per hectare. The well off farmers of the Punjab, Haryana and western Uttar Pradesh are applying this input in the given proportion while some of the more ambitious farmers are even exceeding the prescribed limit.

In the developed countries like the UK, Germany, Netherlands and Japan the consumption of chemical fertilizers is much higher to that of India. For example, the per hectare consumption of chemical fertilizers in India is only about 75 kg per hectare as against 525 kg per hectare in the Netherlands and about 500 kg per hectare in Japan. Most of the Indian farmers being poor have very little purchasing power and are unable to supply the prescribed doses of fertilizers. The big farmers of Punjab and Haryana are, however, applying heavy doses of chemical fertilizers. The national average of NPK consumption is 75 kg per hectare while in Punjab and Haryana the average consumption of chemical fertilizers in about 170 kg and 110 kg per hectare respectively.

Plant Protection Chemicals

The new seeds are very delicate and highly susceptible to pests and disease. The irrigation fields enriched with heavy energy input of NPK create a micro climate (hot and humid) in the field which helps in the luxurious growth of plants. The hot and moist environment of the field also becomes conducive for the fast growth and multiplication of irrigation insects and pests. These insects and pests seriously attack the points, hamper their growth and reduce the yield substan-

tially. The danger of pests and insects may be reduced by using plant protection chemicals. The problem may be tackled either by developing the disease resistant seeds or by spraying insecticides and pesticides at the prescribed schedules devised for different crops.

The problems of crop disease and infestation by insects may also be overcome by timely application of herbicides, fungicides, insecticides, nematicides and rodenticides. For the application of plant protection chemicals the farmers must have adequate knowledge of plant disease and their controlling chemicals. At the outbreak of a disease in the crop the entire area should be sprayed. If the timely spray is not done the crops of the region may vanish. Since the plant protection chemicals are quite expensive, they are generally out of the reach of small and marginal farmers. And if the crops by small farmers are not sprayed, the insects may creep in the neighbouring fields and the disease may adversely affect larger areas.

Capital Constraint

Availability of capital is also a vital constraint in the adoption and successful cultivation of HYV. The adopters of HYV must have operational capital for the purchase of seeds, installation of tubewells, drilling of pumping sets, chemical fertilizers, plant protection chemicals, tractors, harvesters, threshers and other accessories. In case the farmer does not possess the operational capital, he should have an easy access to credit. In India, most of the farmers, excepting a few larger ones, have no surplus over consumption, and therefore, no saving or operational capital at their disposal. The agrarian institutions like banks and cooperative credit societies have great responsibilities. They should advance loans to the farmers at a reasonable rate of interest. Unfortunately, the credit agencies in India, generally, serve the larger farmers who are economically well off and politically well connected. The poor and small farmers are thus deprived of the required inputs, so essential for the successful cultivation of HYV of wheat and rice.

Mechanization

Modern farming tools and technology like tractor, thresher and sprayers are also imperative for the successful cultivation of HYV. These varieties, as stated at the outset, require elaborate arrange-

ments of canal and tubewell irrigation. Raising of three and four crops from the same field in one year is possible only if modern technology is available to the farmer. The traditional plough and bullock-carts are less efficient to finish the agricultural operations on time. Enormous machinery, like tractors, threshers, sprayers, tillers, chaff cutters, pumping sets, etc., are required for the timely operations of sowing, weeding, spraying and harvesting of HYV. The mechanization of agriculture also helps in the judicious utilization of complementary inputs like irrigation water, chemical fertilizers, insecticides and pesticides. For example, a farmer, having a tractor and blade terracer, manages to grade his field to a much better level in the course of time as compared to a farmer not having the similar sources of power and equipments at his disposal. The proper grading and levelling of fields helps in reducing water losses, and economize on labour required for irrigation. Among many useful aids which increase the efficiency of the farmers are seed-cum-fertilizer-drill, well designed plant protection equipments, dunlopcarts, trolley, threshers, sprayers and tractors. Availability of electric power which is the nucleous of all technological development is imperative for multiple cropping under the HYV programme. As a matter of fact, electric power has a vital role in the development and extension of HYV. It supplies the mechanical power to tubewells, pumping sets, threshers, crushers, grinders and chaff cutters.

Transport, Marketing and Storage Facilities

The infrastructural facilities like transport network, marketing and storage facilities are also very crucial for the successful cultivation of HYV. It is the transport network which determines the types of crops grown in an agricultural region. It also helps in the marketing and storage of the agricultural commodities. Once a village is linked with a town by a metalled road, its economy undergoes a remarkable transformation. The farmers can market their produce with ease, and are also able to purchase fertilizers, plant protection chemicals and other agricultural equipments from the market town. This leads to the intensification of agriculture and rapid transformation in the cropping patterns. Cultivation of perishable crops like vegetables, fruits and dairy products can also be done efficiently and profitably if elaborate transport, marketing and storage facilities are available.

HYV can also fetch handsome amounts to the farmers only if a good market for the disposal of the commodity is available within a short distance of the place of production. Efficient transport and nearness to the market reduce the cost of transportation of the bulky and perishable agricultural commodities. In the initial years of the Green Revolution (1968-70), in the states of Punjab and Haryana, the crop of wheat was largely damaged in the threshing grounds owing to the untimely rainfalls in the months of April and May. Similarly, in 1970-72, large uncovered piles of wheat accumulated at the railway stations of Punjab and Haryana were damaged due to the untimely heavy rainfalls in the month of May. This resulted into heavy losses to the farmers of the region.

Apart from efficient transport and infrastructural facilities, modern flour mills and rice husking factories need to be located at appropriate location. The old mills and factories are unable to handle the increased supplies of wheat and rice. In the absence of these facilities a lot of produce may go as a waste. Moreover, the fluctuations in prices of agricultural commodities reduce the margin of profit of the growers which may work as disincentive for the cultivation of HYV.

Extension Service

For the successful cultivation of HYV, there should be an efficient extension service which may guide the farmers about the various agricultural operations and precautions. The fuller use of inputs may be made only if proper guidance to the cultivators is available. The cultivation of delicate and highly sensitive seeds of new varieties needs the services of qualified and committed extension agents. In the tradition bound Indian society, the efficiency of extension machinery determines largely the efficiency of the producers There should, therefore, be a perfect understanding and coordination between farmers, extension agents, farm supervisors, researchers and agricultural scientists. Any slackness in the work of agricultural machinery may make the agriculture a less profitable pursuit. It is a well established fact that investment in research brings ten times profit to the investor.

Human Factor

In the adoption and spread of HYV the role of human factor is also very important. As a matter of fact, in many cases, man behind the

machine becomes more important than the machine itself. Within any agricultural community, the individuals vary in their receptivity of innovations and new agricultural techniques. The experts and researchers who attempted to assess the role of human element in the adoption of agricultural innovations found great variations in the agricultural practices and yield levels of different farmers living within a micro region of a village. The personal qualities of a farmer, his attitude, beliefs, aspirations, progressiveness, education, lifestyle and family values determine his capacity to adopt an agricultural innovation. In fact, there are innovative and hardworking farmers within a village who perform better than their orthodox neighbours whose efficiency may be comparatively low. In other words, in all societies, there are rational, economic farmers and irrational tradition bound farmers. The progressive and enterprising farmers have largely improved their standard of living by their industry, while the lethargic and orthodox cultivators could not adopt the new technology successfully and many of them are still in the grip of poverty and undernourishment.

The variations in yield and production also determine the assets building process of the farmers. In this world of competition, only those are marching ahead who are progressive, innovative, receptive and efficient, while the conservative and less progressive are left behind. In one study conducted in Punjab, it was found that the Jat farmers are more innovative, energetic and enterprising. The Jat farmers who came to India from Pakistan in 1947 were found more industrious and superior in techniques of cultivation in comparison to the other farmers of Punjab, Haryana and Uttar Pradesh. Similarly, the Jats, Saini and Gadas of western Uttar Pradesh are more enterprising and receptive to new innovations in agriculture.

The lifestyle of the farmers and their aspirations for better standard of living also determine their efficiency. It is mainly because of the human factor that the agricultural incomes of the farmers, having almost the same size of holdings in a village, vary from each other. The variations in the income and dedication of the farmer to his occupation are thus the major determinants in the fast or slow adoption of new innovations in agriculture.

Green Revolution: Performance of Crops

Introduction and diffusion of HYV has substantially increased the production of cereals, especially that of wheat and rice. It is because of the new varieties that India is now exporting wheat and rice to Bangladesh, China, Russia, S.W. Asian countries, Ethiopia, Afghanistan and East European countries. The area under cereal crops has increased appreciably as shown in the following table:

Table 11.1

India: Trend in the Growth of Food and Non-food Crops(1950-91)

(in per cent)

Year	*Food crops*	*Non-food crops*
1950-51	74	26
1960-61	72	28
1970-71	78	22
1980-81	80	20
1990-91	81	19

Source: Computed from the data published by the Directorate of Economics and Statistics, Government of India.

It will be seen from Table 11.1 that in the pre-Green Revolution period (1950-61) there was a steady decline in the percentage of area under food crops, being 74 per cent in 1950-51 and 72 per cent in 1960-61. The farmers during that period were more inclined towards the cultivation of non-cereal crops (sugarcane, cotton, oilseeds, etc.) which used to fetch more money to the farmers. During that period the yield per hectare of wheat and rice was very low. The situation got changed after the Green Revolution. In 1970-71, for example, the area under food crops went up as they occupied 78 per cent of the total cropped area in 1970-71 against 72 per cent in 1960-61. The areal strength of food crops further increased being 80 per cent in 1980-81 and 81 per cent in 1990-91. The steady increase in the area of cereal crops during the last three decades shows that now the farmers of certain areas like Punjab and Haryana are no longer subsistent They are growing wheat and rice largely for the market. In other words, the traditional classification of food crops and commercial crops has lost its significance. Now, wheat and rice are produced by the farmers of

the region of successful Green Revolution to generate income and to fetch more money to the family.

Diffusion of HYV has also changed the areal strength of the different crops. The area under different crops in the pre and post-Green Revolution decades has been given in the following table:

Table 11.2

India· Changes in Areal Strength of Selected Crops(1950- 1991)

(in '000 ha)

Crop	*1950-51*	*1960-61*	*1970-71*	*1980-81*	*1990-91*
Rice	308	341	375	401	390
Wheat	97	129	82	223	236
Total cereals	782	920	17	1042	9715
Pulses	190	235	225	224	218
Sugarcane	17	23	25	27	31
Cotton	59	64	69	78	71

Source: Estimate of area, production and yield, 1950-51 to 1990- 91, Directorate of Economics and Statistics, Government of India.

An examination of Table 11.2 shows that area under wheat and rice has increased significantly, while the area under pulses is almost unchanged. In many districts of the country, especially in Punjab and Haryana, the area under millets, maize and pulses has declined substantially. The area under wheat has recorded an increase of about 150 per cent during the last three decades while the area under rice also recorded a significant increase. The major expansion of rice took place in the states of Punjab and Haryana which may be attributed to the adequate expansion of canal network and the drilling of millions of tubewells and pumping sets. Area under rice increased in the states of Uttar Pradesh, Jammu & Kashmir, Himachal Pradesh and Madhya Pradesh, and the Bharatpur, Alwar and Ganagnagar districts of Rajasthan.

In order to examine the changes in productivity, the average yields of the important crops for the periods of 1960-61 and 1990-91 have been displayed in the following table:

Table 11.3

India. Average Yield of the Major Cereal and Non-cereal Crops(1960-61 and 1990-91)

Crop	Average yield in kg	Average yield in kg	Percentage increase/ decrease
	1960-61	1990-91	
Rice	915	1612	76 17
Wheat	757	2100	177 40
Maize	856	1335	55 95
Jowar	495	725	46 46
Bajra	303	507	66 33
Pulses	493	549	11 36
All foodgrains	652	1256	48 09
Sugarcane*	38	62	63 20
Cotton	105	202	92 38
Jute and mesta	1034	1507	45 74

* Yield of sugarcane in tonnes per hectare

Source Economic Surveys 1990-91 and 1994-95

The data presented in Table 11.3 reveal that the yield of wheat has increased by over 177 per cent between 1960-61 and 1990-91 Rice is the staple food which recorded the second highest increase in yield being over 76 per cent, followed by *bajra* and maize which recorded an increase of 66 per cent and 56 per cent respectively. In the pulses, there was, however, a marginal increase of about 11 per cent only. Pulses, being the main source of protein in the country, need special attention for the enhancement of their yields per unit area. Among the non-cereal crops, cotton recorded an increase of about 92 per cent, followed by sugarcane 63 per cent, while the yield of jute and mesta went up by about 46 per cent

The total production of wheat was only 11 million tonnes in 1960-61 which went up to 59 million tonnes in 1994-95. The high profitability generated by HYV induced the farmers to divert a substantial proportion of their holdings to wheat crop. The rice production rose to 80 million tonnes in 1990-91 as against 35 million tonnes in 1960-61. The overall production of foodgrains was 185 million

tonnes in 1994-95. Production of pulses in the country is, however, oscillating about 10-14 million tonnes for the last 35 years.

In general, during the post-Green Revolution period, the annual growth rate of foodgrains was 2.62 per cent, a little above the rate of population growth. The only setback being in the case of pulses which continue to register a lower growth rate. Consequently, the per capita availability of pulses has come down from 69 grams in 1961 to about 38 grams in 1994. A substantial increase in the production of pulses in necessary to meet the protein requirements of the teeming millions. Sluggish growth in the production of pulses is mainly due to the failure in the development of HYV for the different agroclimatic regions of the country. Some successful work has been done in the case of *arhar* (pegion pea), *moong* (green gram), gram, and black gram, but its impact on enhancing supplies is not yet visible.

A more realistic picture of the performance of HYV and the success or failure of the Green Revolution may be ascertained by examining the performance of the major cereal and non-cereal crops during the last three decades. In order to achieve this objective, the area, yield and production of rice, wheat, maize, millets and pulses have been briefly discussed in the following paras.

Rice

Rice is the staple food for about 60 per cent of the total population of the country. It is grown under diverse temperature, moisture and soil conditions. Availability of moisture either from rains or from irrigation is, however, the main determinant of its cultivation. Cultivation of rice is carried on all over the country excepting the unirrigated parts of Rajasthan, Kutch, Saurashtra, Malwa and Marathwada. After the introduction of HYV, its cultivation has assumed great significance in the cropping structure of Punjab, Haryana and western Uttar Pradesh. The Ganga-Brahmaputra plains, the eastern and western coastal plains, the hill states of northeast India, Chotanagpur plateau, Madhya Pradesh, the valley of Kashmir and the irrigated parts of Himachal Pradesh are the main rice growing areas of the country. Traditionally, the states of Uttar Pradesh, West Bengal, Assam, Madhya Pradesh, Bihar, Orissa, Tamil Nadu, Andhra Pradesh and Kerala were the main growers of rice. The concentration of rice during the pre-Green Revolution and post-Green Revolution periods has been

Figure 11.1

India Rice Concentration, 1961-64

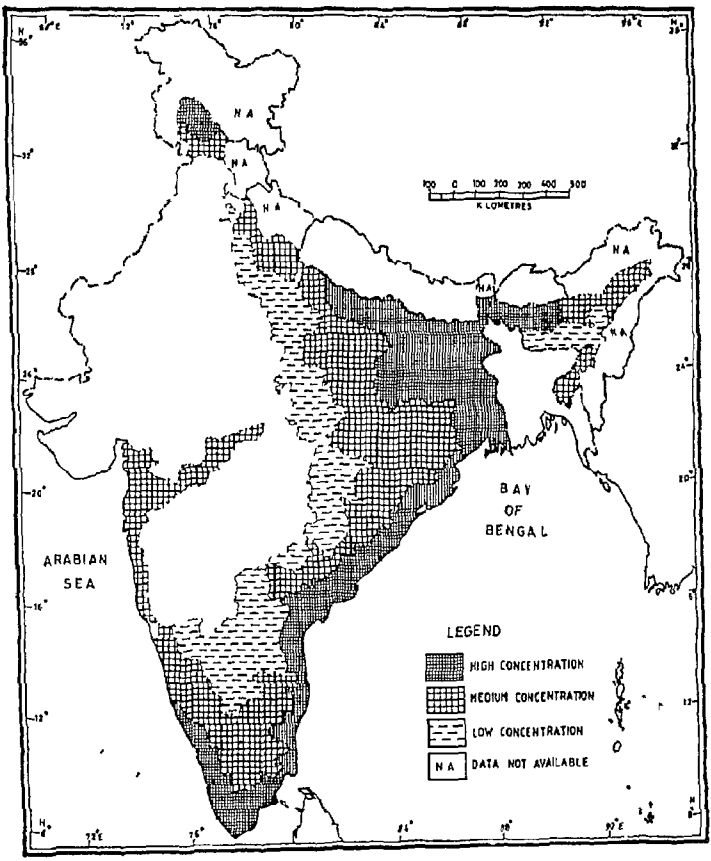
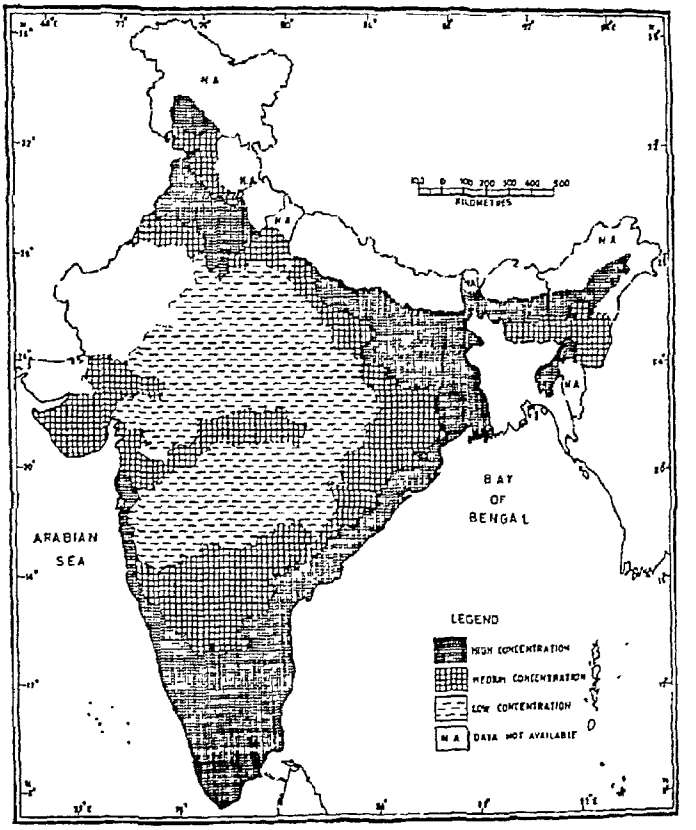


Figure 11.2

India: Rice Concentration, 1991-94



shown in Figures 11.1 and 11.2 while the percentage change in its area, yield and production have been given in the following table:

Table 11.4

India: Area, Production and Yield of the Principal Cereal Crops

(area in thousand hectares
production in thousand tonnes
yield in kg/hectares)

Crop	*Year*	*Area*	*Percentage change in area*	*Production*	*Percentage change in production*	*Yield*	*Percentage change in yield*
Rice	1964-65	36462	16 77	39038	101 15	1078	50 23
	1994-95	42576		78525		1612	
Wheat	1964-65	13422	85 70	12290	376 28	913	130 12
	1994-95	24925		58535		2101	
Maize	1964-65	4618	30 46	4664	8 16	948	40 82
	1994-95	6025		5045		1335	
Jowar	1964-65	18056	-28 23	9749	18 23	543	33 70
	1994-95	12958		11526		726	
Pulses	*1964-65*	*23875*	*-5 82*	*12417*	*17 24*	*495*	*11 11*
	1994-95	22485		14550		550	

Source Directorate of Economics and Statistics, Government of India

As can be seen from Table 11.4 that the areal strength of rice has increased from 364 thousand hectares in 1964-65 to 425 thousand hectares in 1994-95, thereby recording an increase of over 16 per cent. The new areas in which its cultivation has been diffused substantially in the last three decades are Punjab, Haryana, western Uttar Pradesh and Himachal Pradesh (Fig. 11.2). The production of rice was about 39 million tonnes in 1964-65 which rose up to 78 million tonnes in 1994 registering an increase of over 100 per cent.

Although, the yield and production of rice has gone up in all the rice growing areas of the country, it recorded an unparallel growth in area and production in the states of Punjab and Haryana. In these states, the farmers have installed tubewells and pumping sets in almost all the unirrigated tracts. In the semiarid parts of Punjab and Haryana, the average annual rainfall is about 60 cm while for the suc-

cessful cultivation of rice about 100 cm of rainfall is required. The deficiency of moisture in Punjab and Haryana is met by canals and tubewells. The cultivation of rice in the rainfall deficient areas with the help of irrigation is, however, a cause of concern as it is causing numerous ecological problems in the region. An account of some of the ecological consequences emerging owing to rice cultivation in Punjab and Haryana has been given in the subsequent part of this chapter.

Wheat

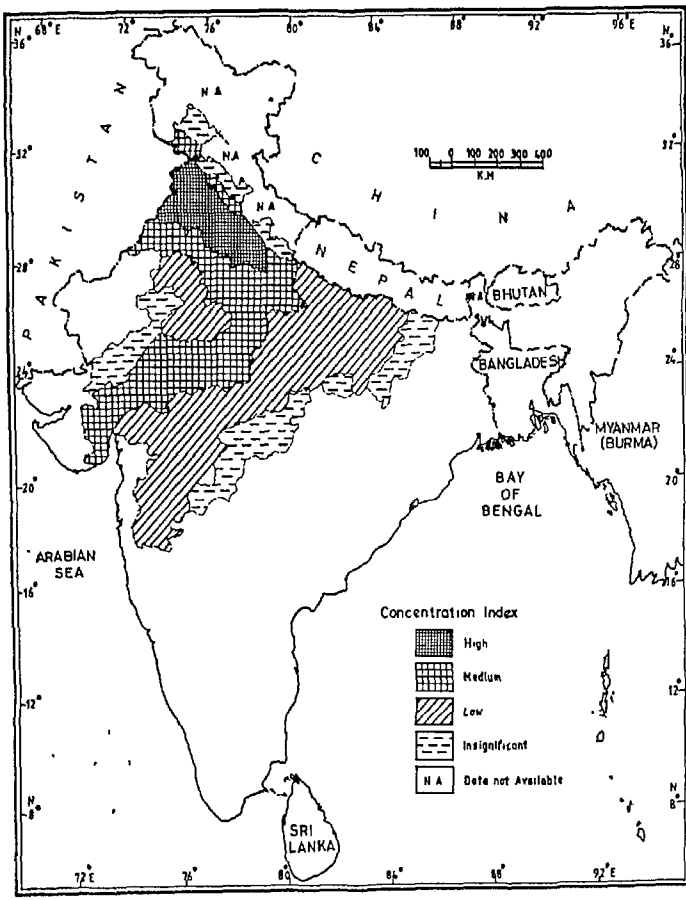
After rice, wheat is the most important food crop in India. It contributes more than 35 per cent of the total foodgrains production in the country. The regional distributions of wheat during the pre-Green Revolution and post-Green Revolution in India have been shown in Figures 11.3 and 11.4, while Table 11.4 gives the changing patterns of its area, production and productivity.

It may be seen from Table 11.4 that wheat is the only cereal in which the Green Revolution is a great success. Its area has expanded substantially and its production and productivity have shown unparallel increase during the last three decades. Between 1964-65 and 1994-95 wheat area has increased from 1.34 million hectares to 2.49 million hectares, thereby, registering an increase of about 86 per cent. The total production of wheat in 1964-65 was 12.29 million tonnes which reached up to 58.33 million tonnes in 1994-95. The per hectare yield went up from 913 kg per hectare in 1964-65 to 2101 kg per hectare in 1994-95.

The regional pattern of wheat distribution shows an overall expansion of wheat area from the Ganganagar district in Rajasthan in the west to Dimapur plain (Nagaland) in the east, and from the Suru and Nubra valleys (Ladakh) in the north to Karnataka in the south (Fig. 11.4). It is not only that wheat has got diffused in all directions from its traditional heartland of Punjab and Haryana, its production and yield also recorded an increase of about 376 and 130 per cent respectively.

Looking at the spread of wheat from the Ganganagar district of Rajasthan to Dimapur of Nagaland and from Ladakh to Karnataka and its excellent performance in the Ganga-Sutlej plain, it may be

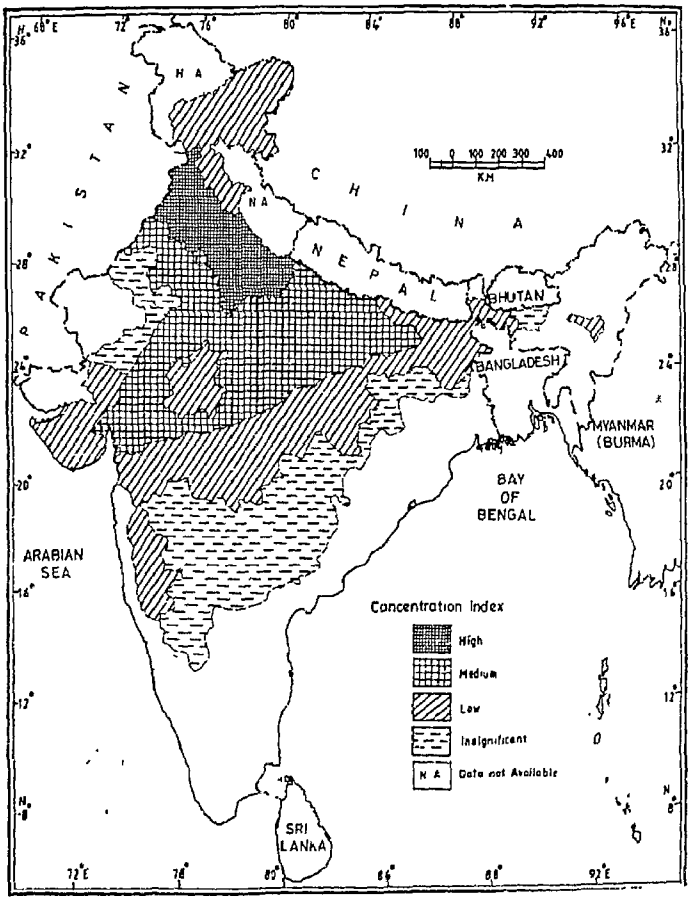
Figure 11.3
India Wheat Concentration, 1961-64



said that the Green Revolution is a great success in the case of wheat Moreover, in Punjab, Haryana and western Uttar Pradesh, it has become a commercial crop. The prosperity of the large and medium farmers of northwest India may be attributed to the diffusion of HYV

Figure 11.4

India: Wheat Concentration, 1991-94

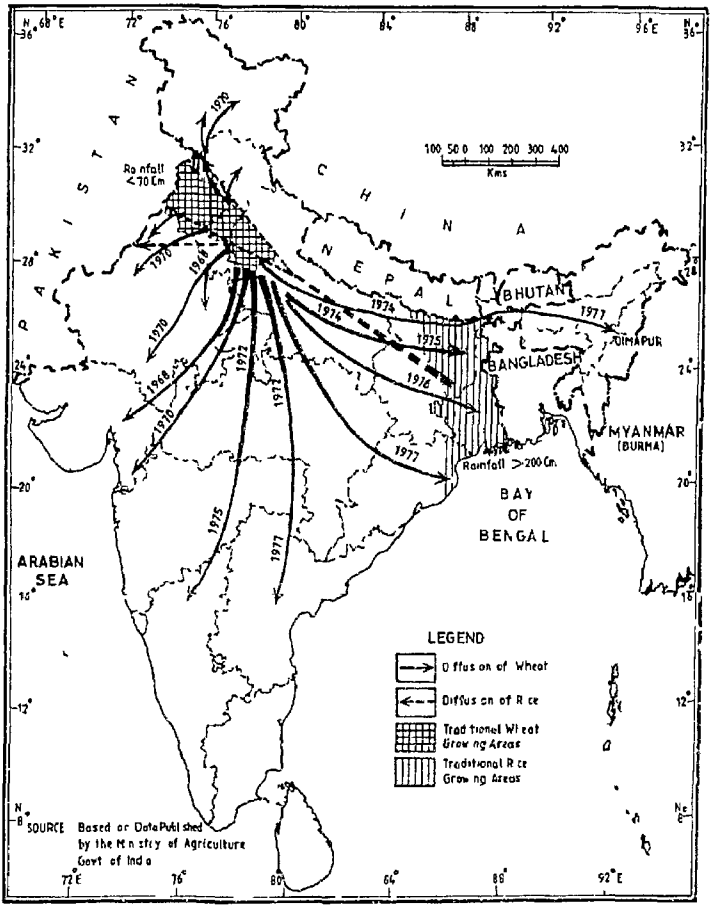


of wheat and rice. The diffusion patterns of wheat and rice have been shown in Fig 11.5.

It may be observed from Fig. 11.5 that Punjab, Haryana and western Uttar Pradesh have emerged as the areas of major concentra-

Figure 11.5

India Diffusion of High Yielding Varieties of Wheat and Rice, 1965-77



tion of rice, while wheat has been diffused in all the directions from its traditional heart land of the north-west India Fig. 11.5.

Maize

Maize is a foodgrain which grows well in the well drained alluvial soils and it requires warm and moist geographical conditions. Its cultivation is, however, carried on in most of the states of the country as a *kharif* (summer season) crop, while in the Kandi (undulating hilly tracts) areas of Kashmir, Ladakh and Himachal Pradesh it is a spring crop. In 1964-65, just before the diffusion of HYV, maize occupied about 4. 6 million hectares, while in 1994-95 its area increased to 6 million hectares. In 1994-95, out of the 6 million hectares, about 2.9 million hectares or 45 per cent of the total area under maize was under HYV. Its area has, however, increased by about 30 per cent during the last three decades, while the corresponding increase in production and yield had been 8 per cent and about 41 per cent respectively (Table 11.4).

Despite the development of HYV of maize, its area has significantly shrinked in the states of Punjab, Haryana and Uttar Pradesh. Rice has encroached upon its area as the farmers are getting more agricultural returns from their fields by doing the cultivation of rice in place of maize during the *kharif* season. It is not only that the per unit area of the yield of maize is lower in comparison to rice, its price per quintal is also low. The farmers have thus generally excluded maize cultivation from their cropping patterns.

Jowar

Prior to the diffusion of HYV of wheat and rice *jowar* was mainly sown for the purpose of fodder in the Ganga-Sutlej plain and for cereals in Maharashtra, Gujarat, Rajasthan and Madhya Pradesh. During the last 30 years, its areal strength has, however, decreased substantially. Its area is now generally devoted to paddy crops in the states of Punjab, Haryana and western Uttar Pradesh. The tractorization and mechanization of agriculture has reduced the importance of bullocks in the farming operations. Consequently, *jowar* has lost its significance as a fodder crop.

In 1964-65, the total area under *jowar* was 18 million hectares which shrinked to 13 million hectares in 1994-95. The introduction

of HYV of *jowar*, however, enhanced its production and productivity by 18 per cent and about 34 per cent respectively (Table 11.4).

In general, the area of *jowar* has decreased in all the states excepting Gujarat and Jammu & Kahsmir. In Punjab, Haryana, Rajasthan, Tamil Nadu, Uttar Pradesh and Madhya Pradesh, the area under millets has been encroached largely by paddy crops.

Pulses

Pulses are the main source of protein in India. They are grown in all parts of the country both in the *kharif* and the *rabi* seasons. Their area, production and yield have, however, not shown any significant increase. Contrary to this, their production declined in the seventies and eighties. Taking the country as a whole, the area under pulses has declined by about 6 per cent in 1994-95 as compared to that of 1964-65. Efforts are being made to develop HYV of various pulses to be diffused in the various agroclimatic regions of the country. The enhancement in the total production of pulses will go a long way in improving the protein quantity in the caloric intake of the Indian masses.

Table 11.5

India: Area under High Yielding Varieties

(in million hectares)

Crop	*1966-67*	*% of HYV area to the total area under the crops*	*1994-95*	*% of HYV area to the total area under the crops*
Rice	0.9	2.6	32 8	68 8
Wheat	0 5	3 9	23 3	88 4
Jowar	0.2	1 1	7.0	52 7
Bajra	0 1	0 8	6 2	53 7
Maize	0.2	3.9	2 9	45 1
Total	1 9		72 2	

Source Economic Survey 1994-95, Government of India, Ministry of Finance, Economic Division.

A comparative picture of the area under HYV of the principal cereal crops has been shown in Table 11.5. It may be seen from Table 11.5 that in 1966-67 only about 2 million hectares of the total

cropped area under cereals (paddy, wheat, *jowar*, *bajra*, maize) was under the HYV and the remaining 98 per cent was under the traditional varieties. The diffusion of HYV has, however, been very fast during the last three decades. It may be corroborated from the fact that in 1994-95 over 72 per cent of the total grain cropped area was under HYV.

An analysis of Table 11.5 makes it clear that at present (1994-95) over 88 per cent of the total area devoted to wheat is under the HYV. It is in the unirrigated areas of Madhya Pradesh, Rajasthan and Ladakh (J&K) where still some of the farmers could not adopt the HYV. The well off farmers of the Sutlej-Ganga plain also devote a small hectarage of their wheat area to the traditional (*desi*) varieties. It is a belief among the farmers of northern India that the *desi* varieties of wheat are superior in taste and are not injurious to health. Contrary to this, the new varieties are considered as largely responsible for some of the dreaded diseases like cancer, liver ailment and blood pressure.

In the case of rice also people have given up the traditional varieties as about 69 per cent of the total rice area was occupied by new seeds in 1994-95. In Punjab, Haryana and western Uttar Pradesh only the HYV are sown, while in the traditional rice growing areas of Assam, West Bengal, Orissa, Bihar and Andhra Pradesh many of the farmers are still in favour of the traditional varieties.

New varieties of millets, *bajra* and maize have also been developed and adopted by the farmers, specially that of the irrigated tracts. The new varieties of *jowar* and *bajra* occupied about 53 per cent and 54 per cent of the area under these crops respectively, while now varieties of maize were sown in 45 per cent of the area under HYV (Table 11.5).

Green Revolution and Rotation of Crops

Rotation of crops is a universal phenomenon which is practised by most of the farmers of the tropical and temperate countries. The main objective of rotation of crops is to obtain higher agricultural returns on the one hand and to maintain the soil fertility on the other. In other words, the rotation of crops helps in making agriculture more sustainable. The importance of crop rotation is more in the areas where

farmers grow two or more than two crops in the same field in a year.

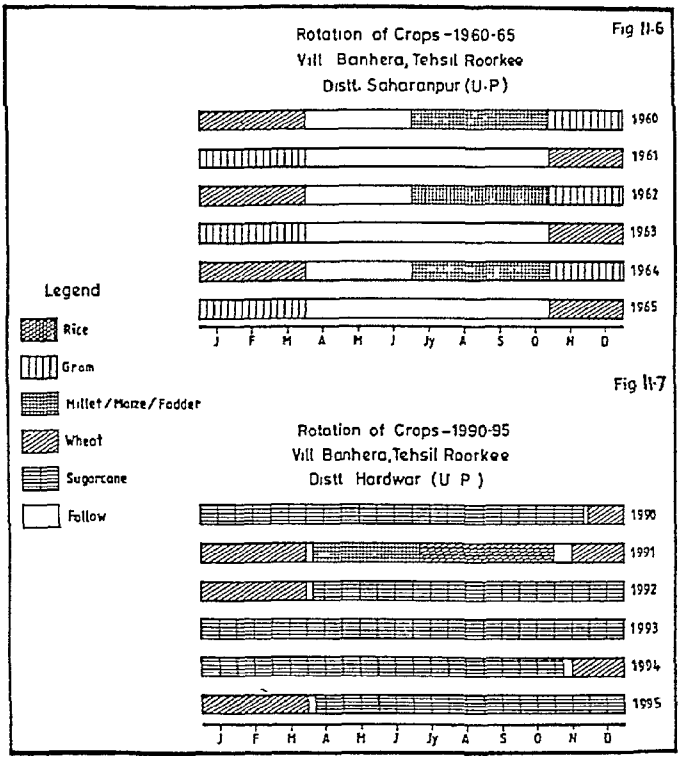
Irrigation facilities have been appreciably developed in the country during the last three decades. The availability of water to the arable land has helped in the intensification of agriculture. As a result of intensification of agriculture and multiple cropping after the diffusion of HYV, the traditional rotation of crops has changed. In some areas, the cultivation of leguminous crops has declined while in other areas they have been completely removed from the cropping structures. Moreover, the practice of fallowing for the recuperation of soil fertility has also been given up. In the areas where the Green Revolution is a big success, like that of Punjab and Haryana, one soil exhaustive crop (rice) is followed by another soil exhaustive crop (wheat). Subsequently, the field vacated by wheat is devoted to either maize or cotton. Thus, in one year, the farmers are harvesting three soil exhaustive crops from the same field. Such a rotation of crop may fetch more income to the farmers but depletes the soil fertility at a faster pace.

Prior to the introduction of HYV most of the Indian farmers were subsistent in character growing crops generally for the family consumption. Now, the agriculture has become agribusiness and more market oriented in which the farmers are concentrating on a few number of crops. Moreover, they are more intensively cultivating their lands to obtain two to three crops in a year. Many of the leguminous crops (pulses) and coarse grains are considered as less remunerative. The concentration of farmers on the cultivation of few soil exhaustive crops (rice, wheat) is a cause of concern as it is creating many environmental and ecological problems.

In order to ascertain the major change in the rotation of crops in the areas where the Green Revolution is a success, the author conducted a number of field studies. The field study about the changes in the rotation of crops was conducted in the village Tarawadi in district Kurukshetra (Haryana) and village Banhera (Tanda) in the district of Hardwar (previously, in the district of Saharanpur, Uttar Pradesh). The main rotations of crops of these villages during the pre-Green Revolution and post-Green Revolution periods have been shown in Figures 11.6 to 11.9.

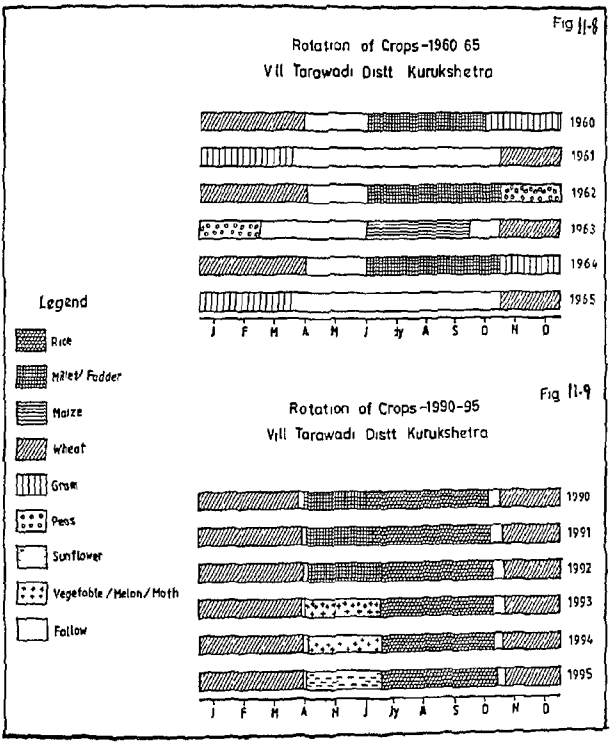
The village Banhera (Tanda) was without any source of irriga-

Figure 11.6 & 11.7



tion prior to the Green Revolution. The farmers of this village, on the basis of their empirical experience, had adopted a rotation of crops in which the soil exhaustive crops used to be sown only after fallowing the land for about 120 days (Fig. 11.6). Once the soil exhaustive crop was harvested, the land used to be devoted to a leguminous crop. Such a rotation of crops and fallowing were helpful in maintaining the fertility of the soil. The drilling of tubewells in the village Banhera (Tanda) helped in the intensification and multiplication of agriculture. At present. the farmers of this village are concentrating on a few crops and have substantially modified their rotations of crops.

Figure 11.8 & 11.9



The main rotations of crops as practised by the farmers during the pre-Green Revolution and post-Green Revolution period have been given in Tables 11.6 and 11 7 respectively.

It may be seen from Table 11.6 that in alternate year the land was left fallow during the *kharif* season to recoup fertility and only after fallowing, the land used to be devoted to wheat (a soil exhaustive crop) Similarly, after harvesting millet/rice in the *kharif*, a leguminous (gram) crop used to be sown in the *rabi* season Such a rotation of crops was quite scientific and helpful in maintaining the fertility of the soil (Fig. 11.6)

Table 11.6

Traditional Rotation of Crops (1950-55) in Banhera (Tanda)

Year	*Kharif (mid-June to mid-October)*	*Rabi (mid-October to mid-April)*	*Zaid (April to June)*	*No. of days land left fallow*
1960	Millet/fodder/rice	Gram	Fallow	90
1960	Fallow	Wheat	Fallow	210
1962	Millet/fodder/rice	Gram	Fallow	90
1963	Fallow	Wheat	Fallow	210
1964	Millet mixed with urad/fodder/rice	Gram	Fallow	90
1965	Fallow	Wheat	Fallow	210

It may also be noted from Table 11.6 that during the period of six years (1959-65) or out of 2290 days the land was left fallow for about 900 days. The land was thus rested for about 40 per cent of the period. Out of the period of occupancy of crop, for about 50 per cent of the period the land was under soil exhaustive crop and for the remaining 50 per cent period under leguminous (gram) crop. The farmers of the village were getting good crops even without the application of irrigation and chemical fertilizers.

After the development of tubewell irrigation in Banhera (Tanda) during the sixties, the cropping pattern of the village has got transformed radically. The rotation of crops, at present, is largely controlled by the availability of irrigation, chemical fertilizers and family labours.

Table 11.7

Modified Rotation of Crop after the Green Revolution(1990-96) in Banhera (Tanda)

Year	*Kharif*	*Rabi*	*Zaid*	*No of days land left fallow*
1990	Rice	Wheat	Sugarcane	5
1991	Sugarcane	Sugarcane	Sugarcane	20
1992	Sugarcane	Sugarcane	Sugarcane	5
1993	Sugarcane	Wheat	Maize	-
1994	Rice	Wheat	Sugarcane	5
1995	Sugarcane	Sugarcane	Sugarcane	5
1996	Sugarcane	Sugarcane	Sugarcane	-

Further, it may be seen from Table 11.7 that in the post-Green Revolution period sugarcane, wheat and rice have become the main crops in the Banhera (Tanda). All these crops are soil exhaustive. Sugarcane alone occupied 52 months out of 72 months (six years) in the new rotation of crops. Moreover, the practice of fallowing of land has almost been stopped. In fact, immediately after the harvest of one crop, the farmers sow the second one. The agriculture of the village is no longer subsistent in character. Undoubtedly, the new cropping pattern is more remunerative and the farmers as well as the dependent labourers are getting more employment and income throughout the year, but from the ecological point of view it is not sustainable. The continuous occupancy of land by the soil exhaustive crops is highly detrimental to the fertility and health of the soil (Fig. 11.7).

The impact of HYV on the rotation of crops has also been illustrated by another example from the Tarawadi village of Kurukshetra district in Haryana. The traditional and modified rotations of crops have been given in Table 11.8 and Table 11.9 respectively.

Table 11.8

Traditional Rotation of Crops (1950-1955) in Tarawadi

Year	*Kharif*	*Rabi*	*Zaid*	*No of days land left fallow*
1950	Millet/maize/fodder	Gram	Fallow	90
1951	Fallow	Wheat	Fallow	120
1952	Millet/maize/fodder	Gram	Fallow	90
1953	Fallow	Wheat	Fallow	120
1954	Millet/maize/fodder	Gram	Fallow	90
1955	Fallow	Wheat	Fallow	120

In village Tarawadi of Kurukshetra district of Haryana, the rotation of crops prior to the Green Revolution, based on the practical experience of the farmers, was quite scientific. In that rotation there was emphasis on fallowing of land after the harvest of every soil exhaustive crop. Moreover, millet and maize which are soil exhaustive crops used to be followed by gram (leguminous crop) to enrich the soil fertility. The farmers by adopting such a rotation of crops were not only getting good crops from the traditional varieties, they were

also taking care of the health of the soil. But, after the diffusion of HYV of rice and wheat, the rotation of crops has undergone radical transformation (Figs. 11.8 and 11.9).

Table 11.9

Modified Rotation of Crops after the Green Revolution (1991-1995) in Tarawadi

Year	*Kharif*	*Rabi*	*Zaid*	*No. of days land left fallow*
1991	Rice	Wheat	Sunflower/vegetables/melons	15
1992	Rice	Wheat	Sunflower/vegetables/melons	15
1993	Rice	Wheat	Sunflower/vegetables/melons	15
1994	Rice	Wheat	Sunflower/vegetables/melons	15
1995	Rice	Wheat	Sunflower/vegetables/melons	15

Further, it may be observed from Table 11.9 that rice and wheat in the *kharif* and *rabi* seasons respectively and vegetables, melons or sunflower in the *zaid* season have emerged as the popular cropping pattern in Tarawadi during the post-Green Revolution period. The farmers, in fact, are more interested in the cultivation of HYV of rice and wheat in the summer and winter seasons respectively. The fallowing of land and cultivation of leguminous crops like gram, *urad* and *moong* have been done away with. The new cropping patterns and rotation of crops have been adopted to maximize the economic gains in short span of time. The land is not left fallow as the farmers are under great family/financial compulsions. The new cropping patterns and rotation of crops are fetching more agricultural returns to the farmers but the ecological cost of such gains is enormous. Thus, what is economically viable may not be environmentally sound and ecologically sustainable. The farmers of Tarawadi village have a strong feeling about the decrease in soil fertility. Many of them reported that the land has become hungry and every year they have to apply more inputs (irrigation and fertilizers etc.) to get satisfactory agricultural output(Fig. 11.9).

During the course of fieldwork various rotations of crops adopted by the farmers of Punjab, Haryana and western Uttar

Pradesh were also observed. The perception of the farmers about the sustainability of agriculture was also probed. It was interesting to note that the farmers of the given region were aware about the merits and demerits of HYV of rice and wheat. The farmers of Punjab, Haryana and western Uttar Pradesh, rated as the most receptive to new ideas and credited with ushering in the Green Revolution, have been reluctant to change the cropping pattern which earned them a fortune during the last three decades. The Green Revolution which tilted the cropping pattern in favour of rice-wheat rotation has highlighted the hazards of monoculture which leads to micro nutrient deficiencies in the soil and progressive dwindling of the underground water table.

Despite the concern from different quarters, diversification has not found support among the farmers. The Johl Committee had suggested that 20 per cent of the area occupied by wheat and paddy crops should be first shifted to other crops and then to other possible farm enterprises,e.g., fruits, vegetables, flowers, forests and fodder for livestock. But very little progress has been made in this direction. The four dominant crops,viz., paddy, sugarcane, cotton and wheat still have a higher profitability than other crops with the single exception of sunflower. But sunflower too has a high water requirement when grown in the spring. Moreover, the profits from wheat, sugarcane, paddy and cotton are assured as their production is not perishable.

One reason why the farmers are not diversifying their cropping patterns and interested in vegetable and fruit cultivation is the lack of processing units. In fact, in the absence of fruit processing units, the farmers had to make distress sales of grapes and kinnows year after year. As vegetables and fruits are highly perishable commodities and there is no fixed procurement rate, many of the farmers suffered heavy losses. The government, therefore, must encourage both the public and private sectors to set up agroprocessing units for various crops, particularly for vegetables and fruits.

Looking at the sustained interest of the farmers in the cultivation of wheat, rice, sugarcane and cotton, a rotation of crops has been suggested by the author in which the soil exhaustive and soil enriching crops have been included. The proposed rotations of crops for sugar-

cane, and rice and wheat growing areas of Punjab, Haryana and western Uttar Pradesh have been presented in Table 11.10 and Table 11.11 respectively.

Table 11.10

Proposed Rotation of Crops for Sugarcane Growing Areas of Punjab, Haryana and Western Uttar Pradesh

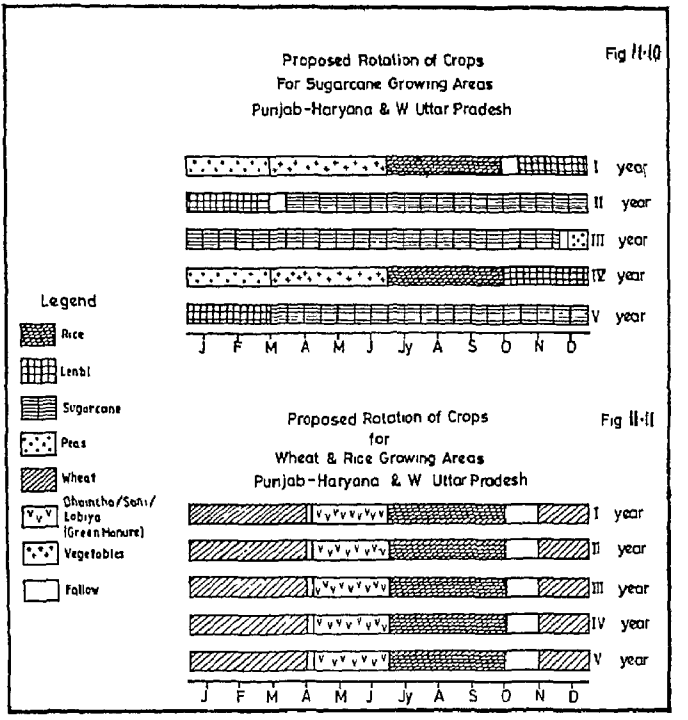
Year	*Kharif*	*Rabi*	*Zaid*	*Land remained occupied by the soil enriching crops*
1st year	Rice	Lentil	Sugarcane	90
2nd year	Sugarcane	Sugarcane	Sugarcane	-
3rd year	Sugarcane	Peas	Vegetables	150
4th year	Paddy	Lentil	Sugarcane	90
5th year	Sugarcane	Sugarcane	Sugarcane	-

Source: Fieldwork by the author.

In the sugarcane growing areas rice (*kharif*) should be followed by lentil (legume) in the *rabi* season before the sowing of sugarcane takes place in the month of March/April. Sugarcane should not remain in the field for more than two consecutive years and after the harvest of paddy the field should be devoted to peas (legume) to be followed by vegetable crops which grow well only if adequate compost and cattle excreta is applied in the field. By obtaining the peas and vegetables the soil fertility shall be replenished. In the subsequent years the field may be devoted to the cultivation of paddy, lentil and sugarcane in the *kharif*, *rabi* and *zaid* seasons respectively. It may also be noted from Table 11.10 that excepting the seasons when sugarcane occupied the field, the land was devoted to leguminous crops for over 90 days (Fig. 11.10).

Over greater parts of Punjab, Haryana and western Uttar Pradesh, paddy in the *kharif* season and wheat in the *rabi* season are the dominant crops. For the wheat and rice growing areas, the rotation of crops as shown in Table 11.11 and plotted in Figure 11.11 may be more scientific and useful for the maintenance of fertility of the soil.

Figure 11.10 & 11.11



As discussed above the farmers are not inclined to diversify their cropping patterns and they are increasingly concentrating on paddy (*kharif*) and wheat (*rabi*) combination. Such a cropping pattern is highly detrimental to the fertility of soil as well as it dwindles the underground water table. The shortcomings of this soil exhaustive combination may be reduced appreciably by sowing a *dhaincha* (green manuring crop)in the month of April. The green manure may be ploughed in the field in the first week of June just before the transplantation of paddy commences.

Table 11.11

Proposed Rotation of Crops for the Rice and Wheat Growing Areas of Punjab, Haryana and Western Uttar Pradesh

Year	*Kharif*	*Rabi*	*Zaid*	*No of days the field remain occupied by soil enriching crop*
1st year	Paddy	Wheat	Dhaincha (Green Manure)	65
2nd year	Paddy	Wheat	Dhaincha	65
3rd year	Paddy	Wheat	Dhaincha	65
4th year	Paddy	Wheat	Dhaincha	65
5th year	Paddy	Wheat	Dhaincha	65

Source Fieldwork by the author

It may also be seen that the soil enriching leguminous crops will occupy the field for about 65 days which shall go a long way in enhancing the fertility of the soil.

Green Revolution: Problems and Prospects

The introduction and diffusion of HYV in Indian agriculture has not only enhanced the production of some of the cereals, they have also created numerous socioeconomic and ecological problems. The production and productivity of wheat, rice and maize have gone up, but the area and production of coarse grains (millets and *bajra*) and pulses have declined in most of the geoclimatic regions. The package programme of HYV adopted in the mid-sixties has substantially changed the cropping structures, the traditional rotation of crops based on empirical experience of the farmers has changed in the areas where the Green Revolution is a success The new seeds have caused interregional and intraregional inequalities in agricultural income. The programme could neither bring the rural poors above the poverty line nor could generate employment in the rural areas at the desired level. Moreover, the farmers are increasingly complaining about the declining fertility of land, lowering of underground water table, diminishing yields of cereal and non-cereal crops and overall degradation of environment. The traditional institutions of rural soci-

ety like mutual cooperation and reciprocal aid system have been destroyed.

The social values of rural society are changing fast, and modernism is making dent in the tradition bound Indian society. These developments are the cause of glaring economic disparities resulting into social tension. A concise account of some of the major socioecological problems arising out of the diffusion of HYV has been given hereunder.

Regional Inequalities

HYV as discussed at the outset are quite delicate and very sensitive which require the timely application of costly inputs (water, fertilizers, insecticides and pesticides). Besides, they perform better in the areas where infrastructural facilities are available and in the holdings of those farmers who can afford to apply the costly inputs in the right proportion and at the right time. In fact, the HYV are giving good returns in the regions with favourable geographical settings(soils, temperatures and rainfall) and/or with substantial past investment on infrastrucural facilities, such as power, irrigation, roads, marketing and storage facilities. The areas with such facilities had already been relatively ahead in terms of yields per hectare and per capita agricultural income. Contrary to this, the areas of extreme climate (hot, cold, wet and dry), poor soils and inadequate infrastructural facilities could not achieve much success by adopting HYV. As a result, the gap in the income of farmers living in different geoclimatic settings has increased. For example, the agricultural income of the farmers of Punjab, Haryana and western Uttar Pradesh has gone up tremendously, while that of the farmers of Rajasthan, Marathawada, Bihar, Orissa, Assam and the hill states of Northeast India has not shown substantial increase. This has accentuated the interregional disparities in the levels of agricultural development. As the new seeds perform better in the areas of assured and controlled irrigation, they bypass those farmers who operate on unirrigated lands. In India, still over 50 per cent of the operational holdings (fields) are without irrigation. The farmers of unirrigated tracts could not adopt the new seeds successfully, and consequently, they are in the grip of abject poverty, suffering from undernourishment and deficiency diseases.

The problem of interregional inequalities may accentuate further

as satisfactory programmes for the rainfed and drought prone areas of the country have not been adequately developed. Since the farmers of the rainfed areas could not adopt the HYV, they are concentrating on subsistence farming and lagging behind in agricultural development.

Intraregional Inequalities

Apart from the interregional inequalities the HYV have also created intraregional inequalities in the agricultural incomes of the farmers living in the same tract/region/village. In other words, even in those areas where the Green Revolution is a big success, all the farmers have not been benefitted equally. It is the large, progressive and educated farmers who gained much from HYV, while the small and marginal farmers whose risk taking capacity is low could not achieve much success. It is an established fact that within a region, those who adopted HYV in the beginning got better agricultural returns. The early starters reaped much dividends from the new seeds. By the time the majority come to adopt the innovation, income gains realized by the early adopters generally disappear. The average farmer, therefore, does not gain much, while the late adopters gain almost nothing. According to the generalized model of community adoption process, after a slow start, adoption of an innovation by farmers increases at an accelerated rate till about half the potential adopters come to adopt it, thereafter, adoption increased but at a diminishing rate. The adopting farmers percentage of the new technology starts at a slow rate in the initial stage, rapidly in the second stage and then tapers off. Thus, the adoption can be classified in the categories of early adopters, majority adopters and late adopters. The distinctive characteristics of the early adopters are generally that they are younger, educated, progressive, venturesome and willing to take risk. They operate relatively large farms and have better social status. Late adopters, in contrast, are generally, older, less educated, orthodox, security minded, small farmers with low income. They are complacent, apprehensive and skeptical and have a lower social status. It has also been found that when the cost of investment is relatively cheaper than labour, the spread between the best practice technique and the average will tend to be narrow. By analogy, the lower the relative cost of material inputs in agriculture, the more widespread will be the pattern of an in-

novation. Contrary to this, when the cost of investment is high to labour, the material inputs will not be widely used.

In brief, the HYV have had a discriminatory impact as they are intensive in their use of material impacts, especially irrigation, fertilizers and market imperfection restrict the access of small farmers to many factor markets, particularly credit. Owing to these constraints, within a geoclimatic setting the large farmers and early adopters have been substantially benefitted from the new seeds, while the small and marginal farmers have been left behind. The growing chasm in the income base of the large and small farmers has created many socio-economic problems, resulting into polarization of rural society which accentuated social tension.

Intercrop Disparities

After the adoption of HYV, the production and productivity of wheat, rice, maize and *bajra* (bulrush millet) have gone up. There are several cereal and non-cereal crops which are not performing satisfactorily The coarse grains, small millets, pulses (lentil, black gram, green gram, red gram),gram and barley are showing steady decline in their area and production. The per hectare yield of wheat and rice in which the Green Revolution is considered to be a great success, show considerable spatial variations in yield and production. For example, while wheat and rice are giving very encouraging returns in Punjab, Haryana and western Uttar Pradesh, their yield and production are very low in the unirrigated tracts of the country. This suggests that the spread of HYV is highly localized and only wheat, rice, maize and *bajra* performed superbly in some of the regions. It is in the case of *kharif* crops, especially pulses, where the performance needs much to be improved. Development of new seeds of pulses for each agro-climatic region, therefore, is the pressing need of the day.

Farm Size Variations

When the package programme for agricultural development was introduced in India, it was expected that the new seeds will be neutral to the scale. In other words, it was conceived that HYV will not be biased towards the large farmers. This assumption has been proved wrong and the new seeds are no longer neutral to the scale.

In any given agroclimatic setting in India, there are four catego-

ries of rural people for whom the benefits arising out of the agricultural innovation may be very different. These categories consist of (i) the large farmers, (ii) the small and marginal farmers, (iii) the tenant farmers, and (iv) the landless labourers. It would be worthwhile to discuss the impact of the Green Revolution on the various categories of people who are dependent on agriculture.

Large Farmers

The definition of large farmers differs from state to state and region to region in India. For example, a farmer having about 10 acres in the states of Kerala and West Bengal is considered to be a large farmer, while in the states of Punjab, Haryana and Rajasthan he falls under the category of medium or small farmer. All the studies conducted in the areas where the Green Revolution is a success show that the large farmers have been the main gainers of the package programme. In the initial phase of the Green Revolution, the large farmers were able to adopt HYV easily. The new varieties increased their savings both to buy machinery that can displace labour and to purchase more land. This trend increased the income base of those who were already relatively well off and better placed in the society. The large farmers are in fact in a position to make the best use of tractors, threshers and sprayers. Moreover, the big farmers purchased pumping sets and installed tubewells for an effective utilization of the underground water table. It has been estimated that for the installation of a tubewell a minimum command area between 10 and 20 hectares is required for a standard 10 cm (4 inches) tubewell, below which the cost of irrigation rises sharply. For the purchase of agricultural machinery, installation of tubewell and other costly inputs credit was essential. Since the large farmers have more risk bearing capacity, they could modernize their agriculture easily. Small, marginal and poor farmers being constrained by financial resources could not adopt HYV in the early phase of their diffusion. Consequently, they lagged behind in the adoption of new agricultural innovations.

In general, the complexity of farming increases with multiple cropping as more inputs and timely operations are required for good harvests. Intensification of agriculture and multiple cropping means more risk. The agrarian institutions, credit agencies and extension service generally serve the larger and powerful farmers, as a result of

which the small and marginal farmers are deprived of adequate inputs so essential for the successful cultivation of HYV. The big farmers who have close connections with the money economy are able to complete their agricultural operations more rapidly than small farmers who rely on family labour for production. This has accentuated the income inequalities in the rural society, and led to the polarization of rural masses.

Small Farmers

The small farmers generally have less than two hectares of land while the marginal farmers possess less than one acre of arable land. These farmers are not well placed technologically and financially. Moreover, they do not have an easy access to the credit agencies. For the irrigation of their crops they have to depend on large farmers. It has been observed that at the time of peak irrigation demand, the tubewell owners (large farmers) either do not give water to the small farmers or they charge exuberantly for the water which is often beyond the reach of small farmers. Owing to the non-availability of timely irrigation water, the crops of small farmers suffer adversely. Over the period of time, such farmers, by taking the advantage of rising land prices, sell out their land and attempt a new start in life.

Agrarian institutions which are supposed to assist the small and marginal farmers are also not very helpful. The credit agencies and extension service, for instance, are largely serving the big farmers who are economically well off and politically powerful. The big farmers could easily preempt for their own use the bulk, if not the entire supply of costly inputs like electricity, water, fertilizers, insecticides and pesticides. Thus, the poor farmers have been deprived of enough inputs so essential for the successful cultivation of HYV.

A survey conducted about the transfer of agricultural land in the village Banhera (Tanda) shows that 80 per cent of the sales were done by the small and marginal farmers, 18 per cent by the medium farmers and only 2 per cent by the large farmers. The purchasers of land were invariably the big farmers who purchased 90 per cent of the total transfers, while the remaining 10 per cent were purchased by the farmers having medium size of holdings.

Tenant Farmers

The introduction of HYV also affected adversely the tenant farmers. In general, the tenant farmers have a low tendency for the adoption of new innovations as they are not very sure for how long the land will be available to them for cultivation. The difficulties of tenant farmers have multiplied by the astronomical rise in the value of land after the diffusion of HYV. The tenants want to lease more land while landowners are reorganizing the gains to be achieved by direct management of their fields. Now land is much more valuable, landlords are reluctant to get into a position where their tenants might be given title of the land. Numerous evasive tactics have been adopted by the landlords. Some of them have directly evicted their tenants from establishing security of tenure by shifting them frequently. In the absence of more effective land reforms, the prospect is for large number of tenant farmers to join the ranks of landless labourers. Compelled by financial crisis, they migrate to big cities in search of employment.

Landless Labourers

One of the assumptions that HYV will generate more employment could also not be achieved. Undoubtedly, the wages of the unorganized agricultural workers have risen by about ten times. In many cases the share of wages has declined, and in some instances real wages rates or the number of days worked, or both, have declined. This has occurred most notably when the diffusion of HYV has been accompanied by labour displacing tractorization and mechanization. Partly this happened because of the more labour supply due to natural increase, and demographic expansion. Consequently, unemployment has increased in the rural areas, forcing the youths to outmigrate in search of some employment in towns and cities.

In the areas where wheat and rice have made spectacular performance, agriculture has been intensified to the extent that farmers are growing three to four crops in an agricultural year. In such areas labourers are finding work all the year round. They find work in the cultivation of crops during the growing season, while during the off season they work on levelling of fields, construction of roads, repairing of irrigation channels and construction of house.

The new seeds also provided indirect employment opportunities

to the landless workers. Employment opportunities have been made available in marketing of seeds, fertilizers, chemicals, insecticides, manufacturing of equipments and marketing and storage of agricultural produce.

In recent decades, landless workers are being attracted towards the agriculturally advance districts of Punjab, Haryana and western Uttar Pradesh from the states of Bihar, Orissa, Himachal Pradesh, eastern Uttar Pradesh and Rajasthan. In brief, although employment in the rural areas has increased but not at the desired level. The natural growth of population has accentuated the unemployment problem in rural India. The mechanization and tractorization of agricultural farms of the big farmers have also displaced the agricultural workers who are increasingly moving towards the big cities.

It is not only that the farmers of a village are not equally benefited from HYV, the cropping patterns, technology, inputs, productivity and sustainability of land also differ from caste to caste and from small to the large farmers.

The influence of caste and size of holding in the upper Ganga-Yamuna doab has been shown in Figure 11.12. Accordingly, the large farmers belonging to the Brahmin, Gujar, Jat, Muslim and Rajput communities prefer to devote their land to rice, wheat and sugarcane. Their agriculture is market oriented. Most of their agricultural operations are being done with the help of modern technology (tractor, trolly, threshers, etc.). They have their personal tubewells and pumping sets which assure timely supply of water to the crops. Chemical fertilizers, insecticides and pesticides are applied in heavy doses to enhance soil fertility and check pests and diseases. Use of cowdung and compost manure by them to their crops is rare. Cultivation of soil exhaustive crops like wheat, rice and sugarcane and inadequate supply of manures are detrimental to soil fertility. Their per unit production is low as compared to the medium and small farmers and their agriculture is less sustainable.

The medium size farmers belonging to the same communities including the Sainis generally grow rice, wheat, sugarcane and fodder (millets, maize, barseem). Fodder is grown mainly to be sold in the neighbouring markets to earn some cash. They are largely dependent on family labour and apply adequate cowdung and compost manures

Figure 11.12

Upper Ganga-Yamuna Doab Size of Holding, Cropping Pattern, Technology, and Sustainability of Arable Land

Size of Holding		*Caste*	*Dominant Crops Grown*	*Manures/ Fertilizers*	*Technology*	*Level of Production*	*Sustainability*
1	Large Farmers	Rajputs, Gujars, Brahmins, Jats, Muslims	Wheat, rice, sugarcane, fodder for domestic cattle	Mainly chemical fertilizers	Tractor/trolly, harvesters threshers	1	Low
2	Medium Farmers	Rajputs, Brahmins, Jats, Gujars, Saimis, Muslims	Wheat, rice, sugarcane, fodder for market	NPK, cowdung, compost manure	Buffalo-cart (*Jhota-Bogi*)	2	Fairly good
3	Small and Marginal Farmers	Saimis, Muslims, Harijans	Wheat, rice, vegetables for market	Cowdung, compost manure, little NPK	Manual	3	High

Source Field survey by the author in the form of structured questionnaries, 1990-96

to their crops to enhance soil fertility. Ploughing of fields is done by bullocks, and buffalocart (*Jhota-Bogi*) is their main mode of transportation for the agricultural commodities. Their productivity per unit area is higher than that of the large farmers and their agriculture is more ecofriendly and sustainable.

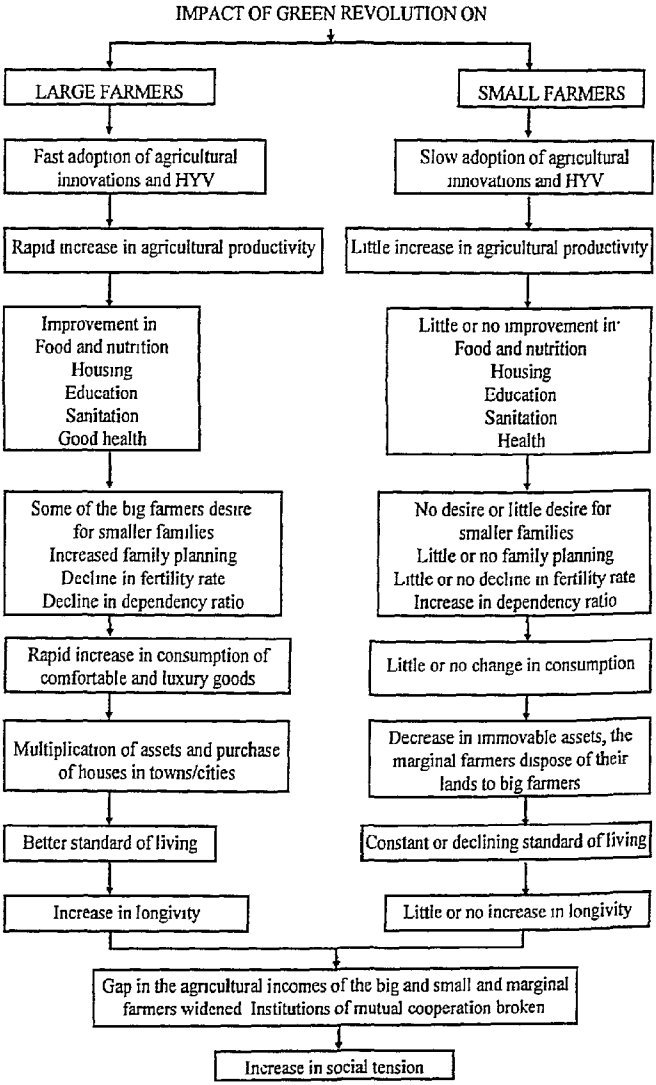
The small and marginal farmers of the upper Ganga-Yamuna doab, comprising Harijans, Sainis, Muslims and other higher castes, generally grow rice and wheat in the *kharif* and *rabi* seasons for family consumption. Moreover, they concentrate on the cultivation of vegetables throughout the year, especially during the summer season which they carry on their heads to the market. Their agriculture is labour intensive and manures are regularly applied in adequate quantities to enhance soil fertility. The per unit production of small and marginal farmers is almost three times than that of the large farmers. Their agriculture is highly sustainable.

It is interesting to note that the large farmers who are largely dependent on modern technology and chemical fertlizers are increasingly complaining about the fast depleting fertility of soil and appearance of saline and alikaline formations in their fields.

The impact of new agricultural strategy, adopted in India in the mid-sixties on the big and small farmers, has been represented diagrammetically in Figure 11.13. It reveals that the large farmers who generally have a better risk taking capacity adopted HYV quickly. They installed tubewells and pumping sets in their holdings and purchased tractors, threshers, harvesters, etc., from the loans they got from the funding agencies of the government. Consequently, their agricultural production and productivity went up substantially Better productivity helped in improving the food and nutritional standard of the big farmers. Improvements also occurred in their housing and clothing. Realising the importance of eduction, many of them sent their children to the English-medium schools and accommodated them in the hostels/rented rooms of the neighbouring towns and cities. The economic prosperity also made them increasingly conscious about health and sanitaion. It was at this stage that some of the big farmers started desiring for small families and they adopted family planning practices. These steps led to a decline in the fertility rate which ultimately reduced the dependency ratio.

Figure 11.13

Social Implications of Green Revolution



The good agricultural returns, economic prosperity and improved social status of the big farmers and social interaction with the urban elites motivated them to construct elegant and spacious *pucca* houses. They started more use of luxury goods which brought consumerism in the rural society. The traditional farmer became a rational economic person who thought all the time to optimize his production and profit. Being too busy in his own affairs he could not care about his neighbours and small and marginal farmers. On the other hand, he started purchasing the arable land of the small farmers which became detrimental to the traditional institutions like mutual cooperation, reciprocal aid system and *bhai-chara* (brotherhood). Some of them, better placed economically, purchased or constructed houses in the neighbouring towns, tehsil or district headquarters to keep their children there so that better education, medical facilities and security may be provided to them. The standard of living of these *famers went up, their life span increased and life became more enjoy*able.

Contrary to this, the small and marginal famers, having less risk taking capacity, could not adopt the agricultural innovations rapidly as they did not like to mortgage their lands for obtaining loans from the funding agencies. Their production and productivity increased marginally. Consequently, there was little or no improvement in their nutrition, eduction, sanitation and health status. Being poor they could not afford to bear the expenses of school education and thought it better to engage their children in agriculture. Realizing the importance of additional hands, such farmers have no desire to have small fimilies and do not adopt family planning. The crude birth rate, death rate, growth rate and the dependency ratio among the small and marginal farmers are high. Owing to constant hard work and incressing mental stress under the changed social milieu, they became more depressed and lost their health. Their standard of living is constantly declining and there is little or no increase in their life span. The widening gap in the income of big and small and marginal farmers broke the traditional mode of life of the rural communities and there is increasing social tension in the rural areas, especially in those where the Green Revolution is a success.

Green Revolution and Social Tension

Despite commendable achievements in the production of crops and almost self-sufficiency in cereals, social tension has arisen and got accentuated during the last three decades. The glaring disparity in income of the farmers originates from the accessibility and availability of agricultural inputs. The big farmers are managing agriculture more efficiently, while the yield of small and marginal farmers could not commensurately match that of large farmers. Owing to great chasm between the incomes of the large and small farmers, the rural society has been polarized.

Intensification and commercializaion of agriculture in the tradition bound society of India in the recent past has increased the importance of agricultural land tremendously. Scarcity of land is being felt in almost all agricultural tracts. In a free market and competitive economy, the worst affected are the small and marginal farmers and the landless labourers. The various steps towards land reforms have also failed to bring about the desired results. In fact, land reform is a costly affair and has profound social consequences. Moreover, what is socially just may not be economically viable, socially acceptable, politically tenable, and environmentally sustainable.

After the Green Revolution, the incidences of rural violence have increased. According to some social scientists, this is the 'red face' of the Green Revolution. The massacre of landless workers at Pipra (1977) by armed musclemen hired by the landlords shocked the entire nation. Pipra was, however, not an isolated tragedy, it was in line with Jansath (Muzaffarnagar, Uttar Pradesh) 1968, Thanjavur (Tamim Nadu) 1969, Belchi (Bihar) 1978, Bishrempur (Bihar) 1978, Deoli (Lakhimpur, Uttar Pradesh) 1981, Sasaram (Bihar) 1987, and several cases in Badun, Etah, Etawah, Agra, Mathura, Meerut, Moradabad, Pilibhit and Shahjanpur (Uttar Pradesh). Thus, the violence has increased with great ferocity in rural India in the last three decades. The causes of social tension may be numerous but it is largely an expression of economic deprivation of the poor farmers and landless labourers which has became accentuated after the introduction of HYV.

One of the main setbacks of the Green Revolution has been that it has destroyed the traditional institution of raciprocal aid system

which was of great help to the cultivators at times of peak labour demand, illness and other unfortunate happenings in the family. In the flood and drought prone areas, the villagers have evolved various risk sharing arrangements aimed at ensuring security subsistence to their members. In the drought prone areas, for example, the socially approved code of conduct induced different categories of farmers to share their surplus of food and fodder with others on a reciprocal basis. The commercialization of cropping patterns, concentration on few crops and development of market oriented economy have largely destroyed the institution of reciprocal aid system. The marginal and small farmers who sold out their lands as a result of socioeconomic pressure have become quite bitter and often criticize the faulty policies of the government which go in favour of the large operational holding farmers. There is no denying the fact that the innovation and diffusion of new seeds are essential for augmenting agricultural production, but the factors which hinder the uniform adoption of HYV in the various agroclimatic region need to be removed. This is an arduous task in which planners, researchers, administrators, farmers and labourers have to work in close cooperation. Their efforts may go a long way towards reducing the regional inequalities and the income disparities of the rural masses on whom the entire economic structure of the country hinges.

Ecological Implications of the Green Revolution

Introduction and diffusion of HYV of wheat, rice, maize and *bajra* (bulrush millet) have undoubtedly stimulated agricultural development. As a matter of fact, the area, production and productivity of wheat and rice have shown substantial increase during the last three decades. Moreover, the farmers in the areas where the Green Revolution is a success have intensified their agriculture. In the process of intensification they have transformed their cropping patterns and changed the sowing dates of their major crops. The big farmers have been benefited more than that of the small and marginal farmers. They have multiplied their material assets, improved their caloric intake and overall standard of living. The landless workers are now having more employment opportunities in agriculture, agrobased industries and other ancillary activities. The Green Revolution has, however, exacerbated social tension. It has also given rise to numer-

ous ecological problems.

Some of the ecological problems emerged out of the Green Revolution are the depletion of forests, reduction of pasture lands, salinization, waterlogging, soil erosion, lowering of underground water table, soil,water and air pollution, reduction in biodiversity, decline in soil fertility, silting of rivers and emergence of several diseases and health hazards. An overview of these ecological problems has been given in the fallowing paras.

Salinization and Waterlogging

The HYV of wheat and rice require several watering. Many a times the farmers overirrigate their crops. The continuous supply of moisture to the soil during the summer and winter seasons have changed the soil chemistry. In the arid and semiarid regions, under the impact of canal and tubewell irrigation, the soil in being adversely affected. Owing to the capillary action, the soils are becoming either saline or alkaline in character. The saline and alkaline affected tracts, locally known as *kaller* in Punjab and *reh* in Uttar Pradesh, have expanded and increased in area. According to one estimate about 50 per cent of the total arable land of Punjab has been harmed by soluble salts. The saline and alkaline affected areas have been plotted in Figure 11.14 and 11.15 which shows that fertile tracts of arable land are being rendered useless from the agricultural point of view. If scientific transformation in the cropping patterns and irrigation practices are not made, more agricultural land may become unproductive.

The problem of salinity and alkalinity may be solved by use of manure and judicious selection of crops that may reduce the proportion of injurious salts. Cultivation of salt tolerant crops like barley, sugarbeet, salt grass, asparagus, spinach and tomato may improve the fertility of such lands.

Another problem associated with irrigation is waterlogging. In all the canal irrigated areas waterlogging is a serious ecological problem. The Indira Gandhi Canal command area is a recent example in which waterlogging is progressively acquiring a serious dimension. Several thousand acres of productive agricultural lands and pastures in the districts of Ganganagar, Bikaner and Jaisalmer in Rajasthan have become waterlogged putting them out of agricultural use (Fig.

Figure 11.14
Sutlej–Ganga Plain:Salt Affected Land

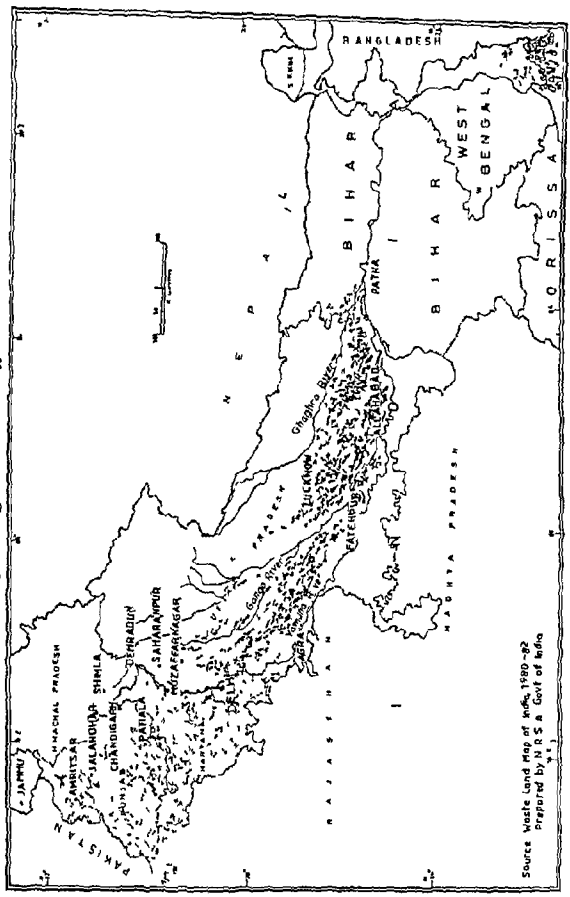
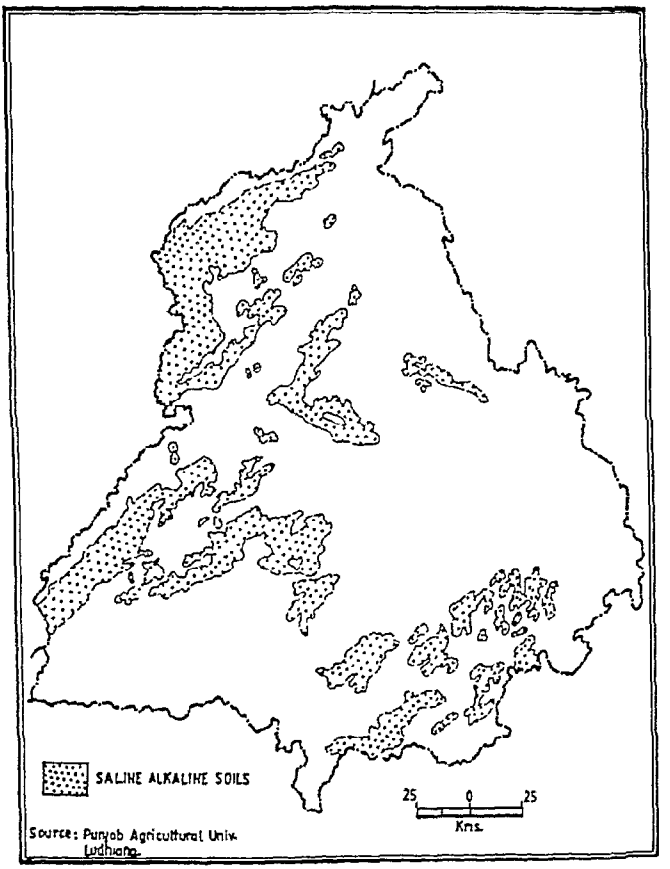
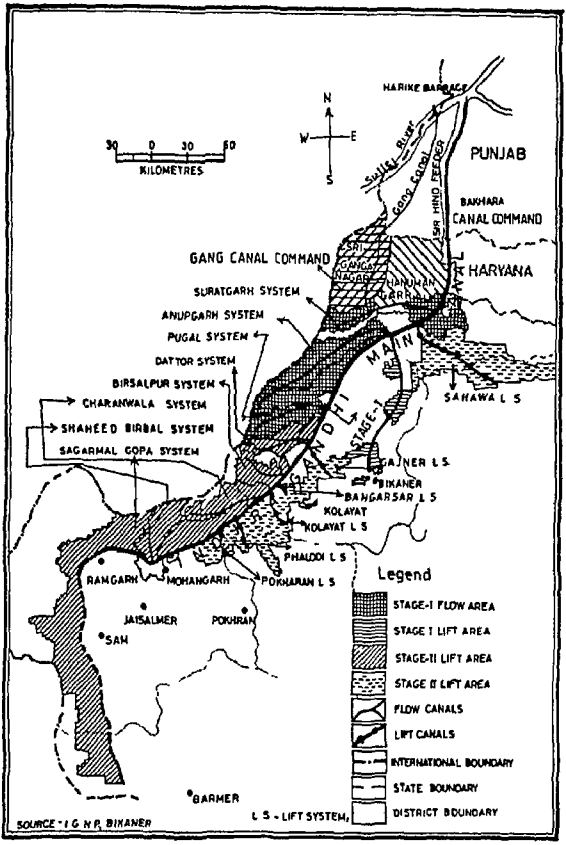


Figure 11.15
Punjab: Soil Salinity



11.16). The ambitious cultivators of the Indira Gandhi Canal command area have changed their land use pattern as they instead of pastures are growing rice and wheat with the help of irrigation. Intensive irrigation of there crops is creating waterlogging and soil depletion problems (Fig. 11.17).

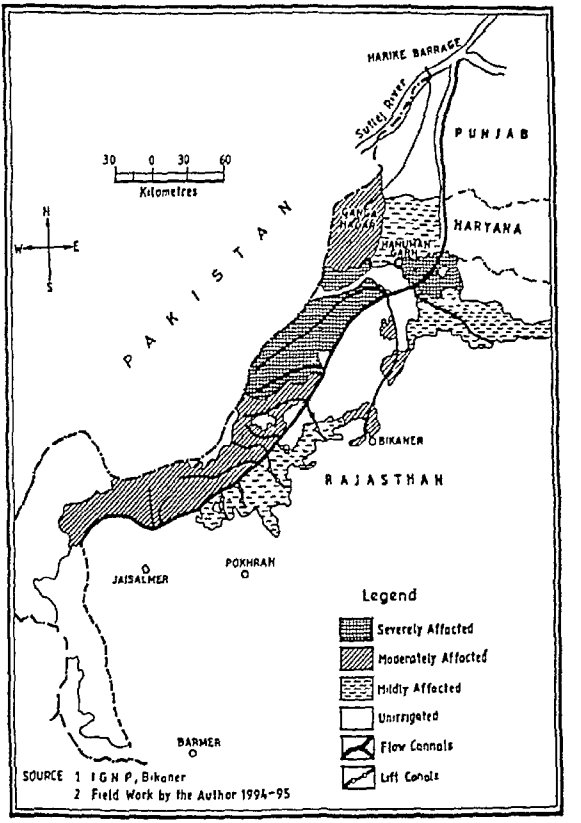
Figure 11.16
Indira Gandhi Canal



Soil Erosion

Soil erosion and leaching of top cover of soils is a universal phenomenon. Although it may be observed in all types of geo-climatic conditions, its intensity is more serious in the arid, semiarid, mountainous and undulating regions. The presence of forest cover reduces the danger of soil erosion significantly. In recent decades the agricul-

Figure 11.17
Indira Gandhi Canal. Salinization and Waterlogging



tural area has been expanded into the pastures and forests which are highly susceptible to soil erosion.

Man's use of land for cultivation of crops over thousands of years and his injudicious agricultural practices have greatly exacerbated the process of soil erosion. The increased rate of soil erosion is not only affecting the areas from which soil is being removed, but

also the areas in which it is deposited. In our country, according to one estimate, about 6000 million tonnes of top soil is leached annually. In the highly productive Sutlej-Ganga plain the ambitious farmers are obtaining three to four crops from the same field in one agricultural year. The traditional rotation of crops has been transformed and the place of leguminous crops (pulses etc.) has been taken by the soil exhaustive crops like rice, wheat, maize, *bajra* and cotton. Consequently, the natural fertility of soil is declining fast. The less productive soils, deficient in humus are generally more vulnerable to soil erosion. If the present rate of soil erosion continues, the alluvial and productive soils of the country would become sterile and unproductive in due course of time.

In order to minimize the danger of soil erosion, the government and the farmers have taken a number of steps. Afforestation and agroforestry are some of the strategies which help in the control of soil erosion. The rationale behind the agroforestry is, however, economically rather than ecologically based. Afforestation is mainly initiated and implemented in an effort to mitigate the effects of deforestation and to ensure the availability of forest resources for the future generation. In the post-Green Revolution period farmers also planted eucalyptus and popular trees along the borders of their fields. These imported varieties of trees though provide fuelwood and raw material to the forest based industry, need a lot of moisture. Their presence has adversely affected the underground water table as they consume a lot of moisture from the fields which otherwise would have been available to the crop.

Pollution

HYV as discussed above demand a lot of moisture through irrigation at regular intervals. The energy requirements in the form of chemical fertilizers are also high. Moreover, the crop needs to be sprayed with plant protection chemicals to reduce the danger of insects and pests. Heavy irrigation of the fields and application of heavy doses of chemical fertilizers and plant protection chemicals have changed the chemical and biological properties of the soils. Puddling of fields before the transplantation of paddy and deep ploughing by tractors have also changed the texture of the soil. The decay of micro organism under the impact of these inputs is a serious problem as the natural fer-

tility of the soil is declining fast and in the absence of compost and green manuring the humus content and nitrogen in the soil cannot be adequately replenished. The overall impact of these inputs is that good patches of agricultural land are becoming sterile and unproductive.

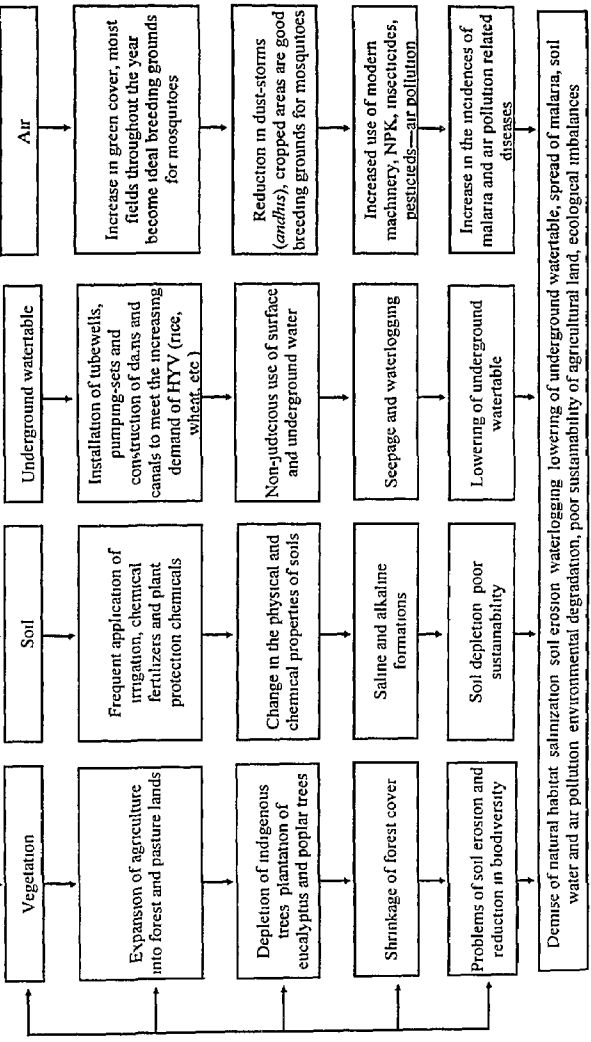
The spatial pattern of the soils adversely affected because of the injudicious management of agriculture have been shown in Figure 11.14. Its may be seen from Figure 11.14 that the intensively irrigated tracts of the Punjab, Haryana, Uttar Pradesh and Bihar in which the farmers are applying heavy doses of chemical fertilizers are the worst affected parts so far as the health of the soil is concerned. The soils of the ill-drained and waterlogged areas are also adversely affected.

Lowering of Underground Water Table

Under the package programmme the area of wheat and rice has increased significantly. Rice has been diffused in the areas of Punjab, Haryana and Rajasthan where rainfall is generally below 50 cm during the rainy season. In these areas, the farmers transplant their paddy crop with the help of irrigation in the month of June when the mean maximum and mean minimum temperatures read around 42°C and 30°C respectively. Rice is a water relishing crop and generally needs over 100 cm of rainfall. In order to meet the water requirements of rice crop, the farmers have to irrigate their fields several times. Wheat crop is also repeatedly irrigated during the winter season. Most of the big and medium holding farmers have installed tubewells in their holdings. The continuous lifting of water almost throughout the year has lowered the underground water table. In the tubewell irrigated areas, the underground water table has gone down 4 to 6 feet. Many of the farmers have to lower and redrill their tubewells owing to the lowering of water table. If the tubewell irrigation continues for the supply of moisture to the crops like rice and vegetables, the apprehension is that the underground water table may not be in a position to recharge. The valuable resource of underground water has thus become increasingly vulnerable after the adoption of the HYV of wheat and rice. Contrary to this, in the areas where canal network is extensive, the underground water able is rising. This rise in the water table is resulting into capillary action and leading to the

Figure 11.18

Impact of Green Revolution on Ecology and Environment



Source Fieldwork by the author in Punjab, Haryana, Western Uttar Pradesh and Rajasthan, 1965-1995

development of saline and alkaline formations. Moreover, the irrigation channels have obstructed the natural flow of drainage and caused waterlogging in the ill-drained areas.

Vegetation Cover

During the last three decades agricultural has been expanded into the forests, pastures and culturable wastes. The lowlying swampy areas and other culturable wastes have been reclaimed for cultivation. Due to the expansion of agriculture the forest and natural areas have shrinked, especially in the plains of the Punjab, Haryana and western Uttar Pradesh. Plantation of eucalyptus and poplar trees in the areas of the Green Revolution is a new phenomenon. The farmers have planted these trees along the margins to their fields. This type of social forestry is not only providing fuelwood to the farmers, but is also fetching handsome amounts to the growers. They also make the micro climates mild.

The plantation of hybrid trees like eucalyptus and poplar has a negative impact on yield of crops as well as on the water table. Since eucalyptus trees demand more water, they dry up the moisture of the neighbouring soil. It has been observed that the per unit production of those fields which have eucalyptus trees on their borders is much lower to those fields which do not have such trees on their margins.

Noise Pollution

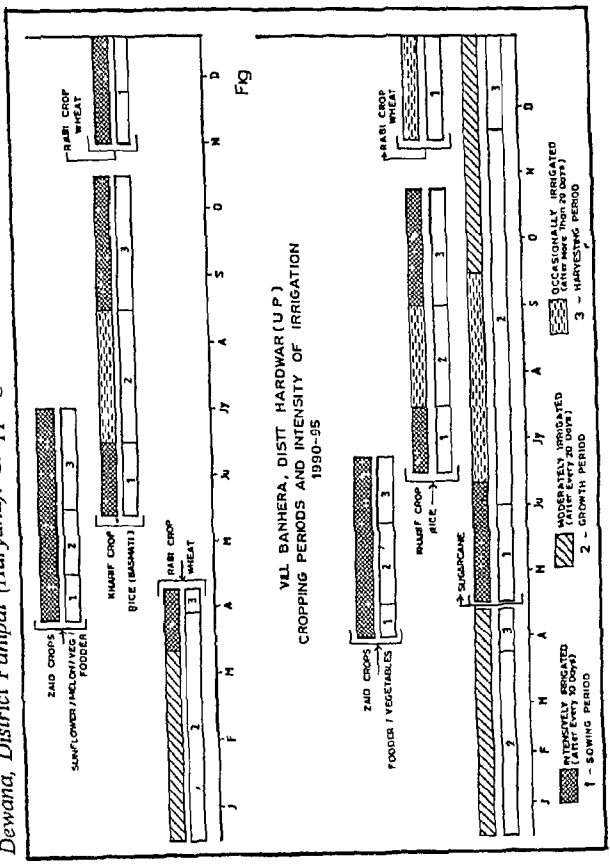
After the adoption of HYV the agriculture has become so intensive that farmers are generally harvesting three crops in a year. The green cover, on the whole, has increased. The regular irrigation to the fields, especially during the summer season, has modified the micro climates.

The danger and frequency of *aandhi* (dust storms) has declined. This may be taken as a favourable effect of the Green Revolution. The change in agricultural technology, the application of tractors, tillers, harrows, threshers, crushers, harvesters, terracers and sprayers have, however, disturbed the rural tranquility and increased noise pollution.

A number of agrobased industries have been located in the rural areas which are not only creating noise pollution but also a social hazard as such factories are the sources of many social evils and

Figure 11.19

Village Dewana, District Panipat (Haryana). Cropping Periods and Intensity of Irrigation 1990-95



Fig

health hazards. The obnoxious odours emitting out of these factories is also a serious problem in rural areas. The agrobased industries located at Gujraula (Moradabad), Daurala (Meerut), Khatauli (Muzaffarnagar), Deoband (Saharanpur), Jagadhri (Yamunanagar), Ludhiana, Jullundhar, Patiala, Kapurthala, Gurdashpur and Ferozpur are creating a lot of noise and air pollution. The noise pollution thus has increased more in the areas where HYV are successful.

Fallowing

Extension in the network of canals and drilling of tubewells and pumping sets have enabled the farmers to harvest two cereals (rice and wheat) and one fodder or cash crop (millet or cotton) in the same field in one agricultural year. The farmers, in order to get more return from their fields, do not leave their land fallow. The continuous use of land and its occupance by the soil exhaustive crops is highly detrimental to the fertility of land. The farmers are aware of this fact and they often complain about the need of more inputs every year to get good returns from their lands. They also complain that the natural fertility of land is steadily declining.

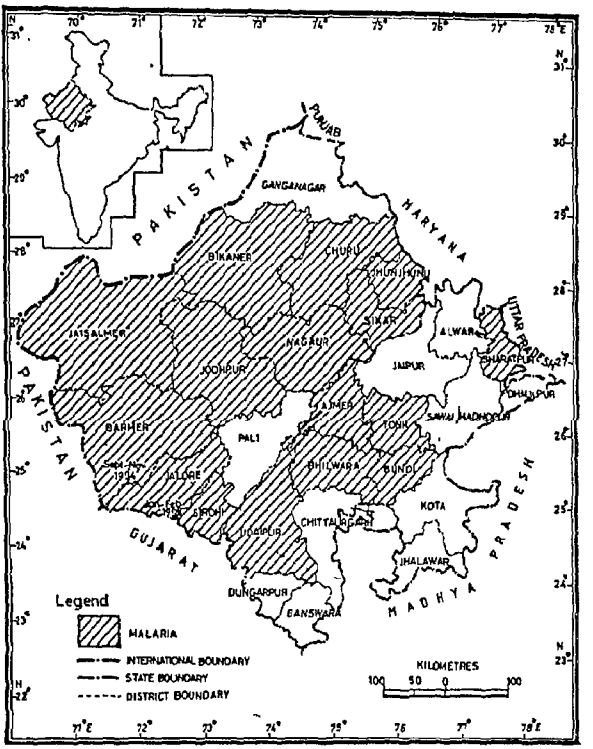
Health Hazards

HYV of wheat and rice as stated earlier need adequate irrigation and heavy doses of chemical fertilizers and plant protection chemicals. The high energy application in the fields in the form of water and fertilizers which is conducive for the luxurious growth of crop are also ideally suited for the fast growth of insects and pests. These insects and pests are controlled by plant protection chemicals. The cereals and vegetables on whom insecticides and pesticides are sprayed are undoubtedly injurious to health.

Crop protection chemicals are compounds that are artificially produced on a large scale to improve the efficiency of crops production by eliminating competition from weeds. These poisonous chemicals are also used on vegetables as well as in the orchards of apples, mangoes, oranges, litchis and guavas.

The Indian Council of Medical Research (ICMR) conducted a survey and revealed the existence of excessive residues of DDT and other pesticides in bovine milk. Traces of lead, copper, zinc, cadmium and arsenic were also detected in rice, wheat, maize, mustard,

Figure 11.20
Rajasthan: Spread of Malaria



cotton, sesame, fruits and vegetables. The contamination of food with chemicals is a major health hazard in India. Moreover, the use of ganochlorine such as gamyxince and DDT has had profound effects on wildlife. Herbicides have altered the balance of weed population so that in solving one problem, others are created. In order to overcome the new problems, new poisonous chemicals are introduced which bring more changes and pollute the environment. The environmental pollution is a health hazard and the increased number of cancer, asthma and breathing problems can be attributed to the re-

cent diffusion of innovations in agriculture.

The recurrence of malaria in the states of Punjab, Haryana and Uttar Pradesh is also being attributed to the moist conditions of the field throughout the year. The moist fields and high temperatures are the ideal breeding grounds for mosquitoes. Every year increasing number of malaria cases are reported in the areas of the Green Revolution. Surprisingly enough, malaria has become a major killer in the arid and semiarid regions of Rajasthan. It may be seen from Figure 11.20 that in 1994 and 1995 the districts of Jaisalmer, Bikaner, Barmer, Jodhpur, Nagpur, Churu, Jhunjhunu, Sikar, Ajmer, Tonk, Bundi, Udaipur, Jalore, Sirohi and Bharatpur reported a large number of malaria cases.

The adoption of HYV has thus brought environmental changes which are detrimental to the soil fertility, deleterious to environmental sustainability and injurious to human health. The reduction in biodiversity in the areas of the Green Revolution may have long term serious ecological consequence. The ecological cost of agricultural development in India is thus quite high and the new seeds of staple foods are resulting into new socioeconomic and environmental problems.

The frequent watering of HYV, application of chemical fertilizers (NPK), heavy doses of synthetic insecticides, and stress on the cultivation of few crops stimulate physiological changes in the soil. The micro organism, so essential for the maintenance of soil fertility, are killed by the application of deadly and persistent poisons and plant protecting chemicals. All these inputs reduce the fertility of soil in the long run. Moreover, the use of synthetic insecticides and pesticides, like DDT, BHC (benzene hexachloride, dieldrin, endrin, carbonates, organophosphates, etc.) on crops exposes human beings to compounds which are health hazards. Looking at the adverse ecological implications of chemical fertilizers and insecticides, some of the developed countries like Japan, USA, Germany, France, UK, New Zealand and Scandinavian countries are increasingly concentrating on biological control of insects and pests. Some of the important methods of biological control insects and pests have been given below:

1. *Biological control of predators and parasites*: It is an ecological

approach of pests and disease control of crops. When a pest problem arises, organism that attack the pests are introduced, and nature takes its course. By importing predators or parasites some degree of permanent control has been achieved in the developed countries of the world.

2. *Biological control by genetic method*: In this method, the males are steriled to check the growth and explosion of insects and pests. It is, however, not a permanent solution of the problem and requires continuous monitoring and research.
3. *Biological control by cultural and hormonal methods*: In this method, the crop ecosystems are modified to the detriment of the pests or to the advantage of their natural enemies. Weeds or crop remains that harbour pests can be destroyed, planting and harvesting dates modified, crops rotated and several crops are sown together.
4. *Integrated control*: Integrated control involves using one or more techniques appropriate to the particular pest situation. For example, mosquitoes may be controlled by draining swamps in which larvae live, stocking lakes with mosquitoe-eating fish or by directly applying toxic non-persistent insecticides to any standing water (ponds, lakes, swamps, etc.) that will not support fish and cannot be drained. Similarly, a crop could be protected by practices as planting it mixed with other crops, destroying pest reservoirs adjacent to fields and by engaging appropriate predators and parasites and by using the non-persistent insecticides. These steps may go a long way in controlling pests and diseases and in keeping the ecosystems in healty condition.

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